CHAPTER 4
ENGINE IGNITION AND ELECTRICAL SYSTEMS

RECIPROCATING ENGINE IGNITION SYSTEMS

The basic requirements for reciprocating engine ignition systems are the same, regardless of the type of engine involved or the make of the components of the ignition system. All ignition systems must deliver a high-tension spark to each cylinder of the engine in firing order at a predetermined number of degrees ahead of the top dead center position of the piston. The voltage output of the system must be such that the spark will jump the gap in the spark plug under all operating conditions.

Ignition systems can be divided into two classifications: battery-ignition or magneto-ignition systems.

Ignition systems are also classified as either single- or dual-ignition systems. The single-ignition system, usually consisting of one magneto and the necessary wiring, was used on most small-volume, slow-speed engines. The single-ignition system is still in use on a few small, opposed-type light aircraft engines.

BATTERY IGNITION SYSTEM

A few aircraft still use a battery ignition system. In this system, the source of energy is a battery or generator, rather than a magneto. This system is similar to that used in most automobiles. A cam driven by the engine opens a set of points to interrupt the flow of current in a primary circuit. The resulting collapsing magnetic field induces a high voltage in the secondary of the ignition coil, which is directed by a distributor to the proper cylinder. Figure 4–1 shows a simplified schematic of a battery ignition system.

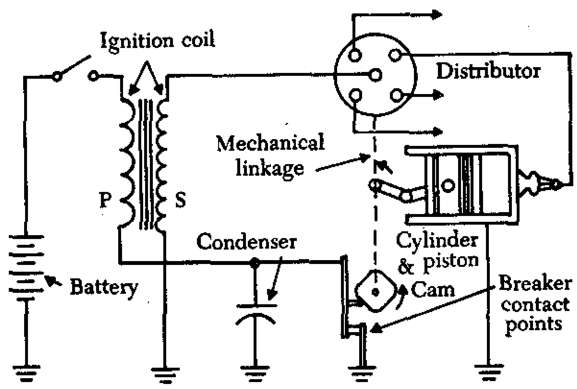


FIGURE 4–1. Battery ignition system.

MAGNETO IGNITION SYSTEM OPERATING PRINCIPLES

The magneto, a special type of engine-driven a.c. generator, uses a permanent magnet as a source of energy. The magneto develops the high voltage which forces a spark to jump across the spark plug gap in each cylinder. Magneto operation is timed to the engine so that a spark occurs only when the piston is on the proper stroke at a specified number of crankshaft degrees before the top-dead-center piston position.

Aircraft magneto ignition systems can be classified as either high tension or low tension. The low-tension magneto system, covered in a later section of this chapter, generates a low voltage, which is distributed to a transformer coil near each spark plug. This system eliminates some problems inherent in the high-tension system.

The high-tension magneto system is the older of the two systems and, despite some disadvantages, is still the most widely used aircraft ignition system.

High-Tension Magneto System

The high-tension magneto system can be divided, for purposes of discussion, into three distinct circuits. These are: (1) The magnetic, (2) the primary electrical, and (3) the secondary electrical circuits.

The magnetic circuit consists of a permanent multipole rotating magnet, a soft iron core, and pole shoes. The magnet is geared to the aircraft engine and rotates in the gap between two pole shoes to furnish the magnetic lines of force (flux) necessary to produce an electrical voltage. The poles of the magnet are arranged in alternate polarity so that the flux can pass out of the north pole

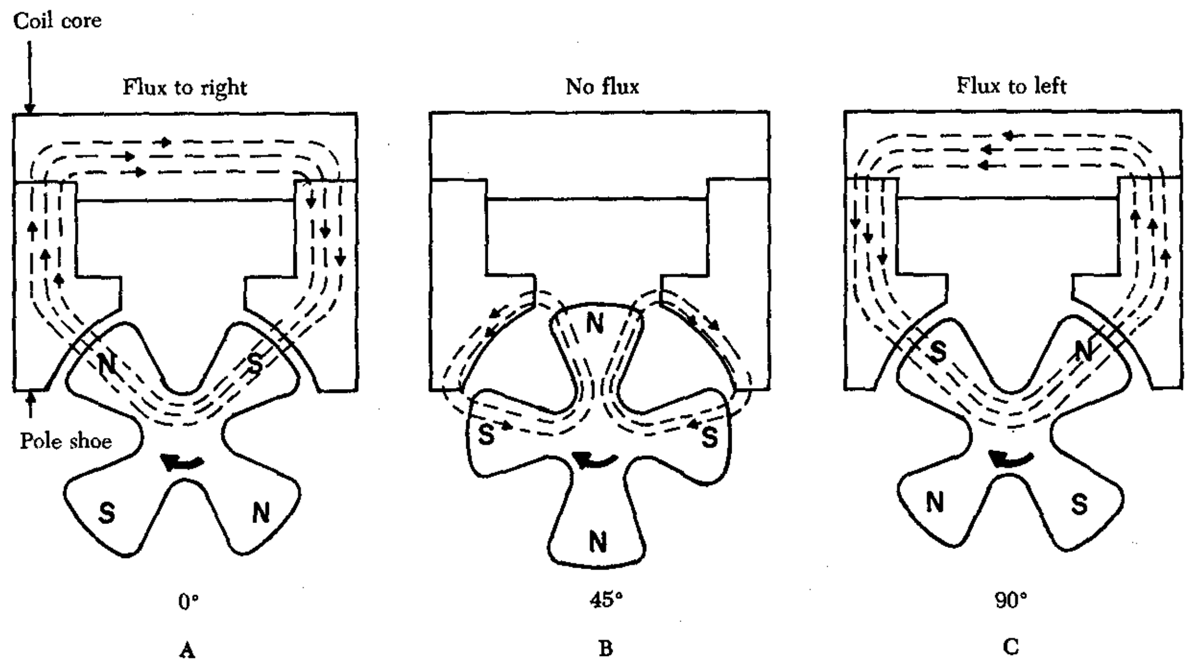


FIGURE 4–2. Magnetic flux at three positions of the rotating magnet.

through the coil core and back to the south pole of the magnet. When the magnet is in the position shown in A of figure 4–2, the number of magnetic lines of force through the coil core is maximum because two magnetically opposite poles are perfectly aligned with the pole shoes.

This position of the rotating magnet is called the "full-register" position and produces a maximum number of magnetic lines of force (flux flow) clockwise through the magnetic circuit and from left to right through the coil core. When the magnet is moved away from the full register position, the amount of flux passing through the coil core begins to decrease. This results because the magnet's poles are moving away from the pole shoes, allowing some lines of flux to take a shorter path through the ends of the pole shoes.

As the magnet moves farther and farther from the full-register position, more and more lines of flux are short-circuited through the pole-shoe ends. Finally, at the neutral position (45° from the full-register position) all flux lines are short-circuited, and no flux flows through the coil core (B of figure 4–2). As the magnet moves from full register to the neutral position, the number of flux lines through the coil core decreases in the same manner as the gradual collapse of flux in the magnetic field of an ordinary electromagnet.

The neutral position of the magnet is that position where one of the poles of the magnet is centered between the pole shoes of the magnetic circuit. As the magnet is moved clockwise from this position, the lines of flux that had been short-circuited through the pole-shoe ends begin to flow through the coil core again. But this time the flux lines flow through the coil core in the opposite direction, as shown in C of figure 4–2. The flux flow reverses as the magnet moves out of the neutral position because the north pole of the rotating permanent magnet is opposite the right pole shoe instead of the left, as illustrated in A of figure 4–2.

When the magnet is again moved a total of 90°, another full-register position is reached, with a maximum flux flow in the opposite direction. The 90° of magnet travel is illustrated graphically in figure 4–3, where a curve shows how the flux density in the coil core (without a primary coil around the core) changes as the magnet is rotated.

Figure 4–3 shows that as the magnet moves from the full-register position (0°), flux flow decreases and reaches a zero value as it moves into the neutral position (45°). While the magnet moves through the neutral position, flux flow reverses and begins to increase as indicated by the curve below the horizontal line. At the 90° position another position of maximum flux is reached. Thus, for one revolution (360°) of the four-pole magnet, there will be four positions of maximum flux, four positions of zero flux, and four flux reversals.

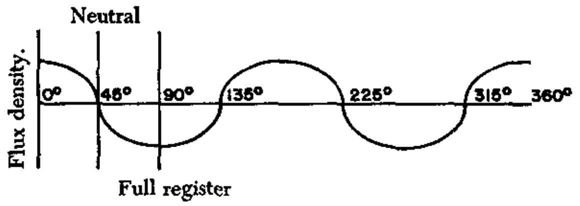


FIGURE 4–3. Change in flux density as magnet rotates.

This discussion of the magnetic circuit demonstrates how the coil core is affected by the rotating magnet. It is subjected to an increasing and decreasing magnetic field, and a change in polarity each 90° of magnet travel.

When a coil of wire as part of the magneto's primary electrical circuit is wound around the coil core, it is also affected by the varying magnetic field.

The primary electrical circuit (figure 4–4) consists of a set of breaker contact points, a condenser, and an insulated coil.

The coil is made up of a few turns of heavy copper wire, one end of which is grounded to the coil core, and the other end to the ungrounded side of the breaker points. (See figure 4–4.) The primary circuit is complete only when the ungrounded breaker point contacts the grounded breaker point. The third unit in the circuit, the condenser (capacitor), is wired in parallel with the breaker points. The condenser prevents arcing at the points when the circuit is opened, and hastens the collapse of the magnetic field about the primary coil.

The primary breaker closes at approximately full-register position. When the breaker points are

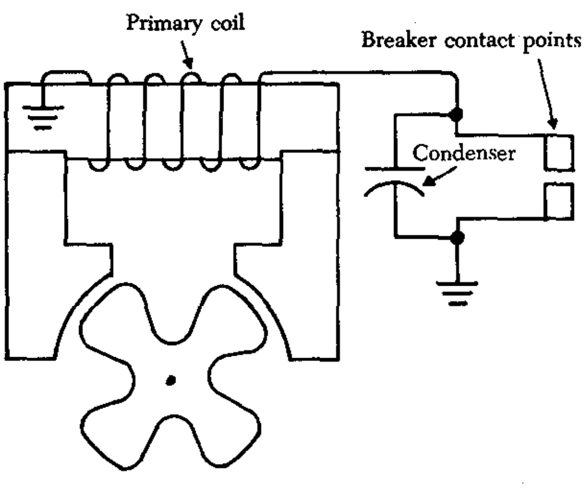


FIGURE 4–4. Primary electrical circuit of a high-tension magneto.

closed, the primary electrical circuit is completed, and the rotating magnet will induce current flow in the primary circuit. This current flow generates its own magnetic field, which is in such a direction that it opposes any change in the magnetic flux of the permanent magnet's circuit.

While the induced current is flowing in the primary circuit, it will oppose any decrease in the magnetic flux in the core. This is in accordance with Lenz's law, stated as follows: "An induced current always flows in such a direction that its magnetism opposes the motion or the change that induced it." (For a review of Lenz's law, refer to the Airframe and Powerplant Mechanics General Handbook, AC 65–9, Chapter 8.) Thus, the current flowing in the primary circuit holds the flux in the core at a high value in one direction until the rotating magnet has time to rotate through the neutral position, to a point a few degrees beyond neutral. This position is called the E-gap position (E stands for "efficiency").

With the magnetic rotor in E-gap position and the primary coil holding the magnetic field of the magnetic circuit in the opposite polarity, a very high rate of flux change can be obtained by opening the primary breaker points. Opening the breaker points stops the flow of current in the primary circuit, and allows the magnetic rotor to quickly reverse the field through the coil core. This sudden flux reversal produces a high rate of flux change in the core, which cuts across the secondary coil of the magneto (wound over and insulated from the primary coil), inducing the pulse of high-voltage current in the secondary needed to fire a spark plug. As the rotor continues to rotate to approximately full-register position, the primary breaker points close again and the cycle is repeated to fire the next spark plug in firing order.

The sequence of events can now be reviewed in greater detail to explain how the state of extreme magnetic stress occurs.

With the breaker points, cam, and condenser connected in the circuit as shown in figure 4–5, the action that takes place as the magnetic rotor turns is depicted by the graph curve in figure 4–6. At the top (A) of figure 4–6 the original static flux curve of the magnets is shown. Shown below the static flux curve is the sequence of opening and closing the magneto breaker points. Note that opening and closing the breaker points is timed by the breaker cam. The points close when a maximum amount of flux is passing through the coil core and open at a

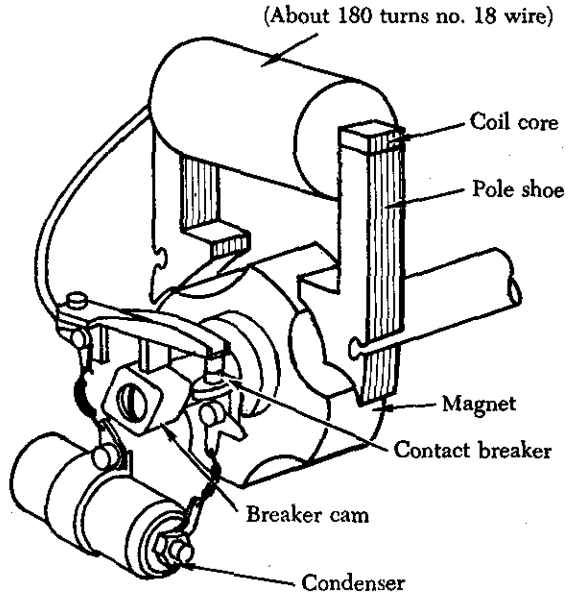


FIGURE 4–5. Components of a high-tension magneto circuit.

position after neutral. Since there are four lobes on the cam, the breaker points will close and open in the same relation to each of the four neutral positions of the rotor magnet. Also, the point opening and point closing intervals are approximately equal.

Starting at the maximum flux position (marked "0°" at the top of figure 4–6), the sequence of events in the following paragraphs occurs.

As the magnet rotor is turned toward the neutral position, the amount of flux through the core starts to decrease (D of figure 4–6). This change in flux linkages induces a current in the primary winding (C of figure 4–6). This induced current creates a magnetic field of its own. This magnetic field opposes the change of flux linkages inducing the current. Without current flowing in the primary coil, the flux in the coil core decreases to zero as the magnet rotor turns to neutral, and starts to increase in the opposite direction (dotted static flux curve in D of figure 4–6). But the electromagnetic action of the primary current prevents the flux from changing and temporarily holds the field instead of allowing it to change (resultant flux line in D of figure 4–6).

As a result of the holding process, there is a very high stress in the magnetic circuit by the time the magnet rotor has reached the position where the breaker points are about to open.

The breaker points, when opened, function with the condenser to interrupt the flow of current in the primary coil, causing an extremely rapid change in flux linkages. The high voltage in the secondary winding discharges across the gap in the spark plug to ignite the fuel/air mixture in the engine cylinder Each spark actually consists of one peak discharge, after which a series of small oscillations takes place. They continue to occur until the voltage becomes too low to maintain the discharge. Current flows in the secondary winding during the time that it takes for the spark to completely discharge. The energy or stress in the magnetic circuit is completely dissipated by the time the contacts close for the production of the next spark.

Breaker Assembly

Breaker assemblies, used in high-tension magneto ignition systems, automatically open and close the primary circuit at the proper time in relation to piston position in the cylinder to which an ignition spark is being furnished. The interruption of the primary current flow is accomplished through a pair of breaker contact points, made of an alloy which resists pitting and burning.

Most breaker points used in aircraft ignition systems are of the pivotless type, in which one of the breaker points is movable and the other stationary (see figure 4–7). The movable breaker point attached to the leaf spring is insulated from the magneto housing and is connected to the primary coil (figure 4–7). The stationary breaker point is grounded to the magneto housing to complete the primary circuit when the points are closed, and can be adjusted so that the points can open at the proper time.

Another part of the breaker assembly is the cam follower which is spring-loaded against the cam by the metal leaf spring. The cam follower is a Micarta block (or similar material) which rides the cam and moves upward to force the movable breaker contact away from the stationary breaker contact each time a lobe of the cam passes beneath the follower. A felt oiler pad is located on the underside of the metal spring leaf to lubricate and prevent corrosion of the cam.

A simpler type of breaker assembly may still be found on some aircraft engines in the lower power range. This type, called the pivot type, has one hinged or pivoted arm with a contact point on the end opposite to the pivot or hinge point. The other contact point is secured to a stationary plate. A rubbing block, usually made of fibrous material, is located near the middle point of the movable breaker arm. When the engine rotates the cam, the lobes exert pressure against the rubbing block, causing the movable breaker arm to swing on its pivot point, opening the contact points.

The breaker-actuating cam may be directly driven by the magneto rotor shaft or through a gear train from the rotor shaft. Most large radial engines use

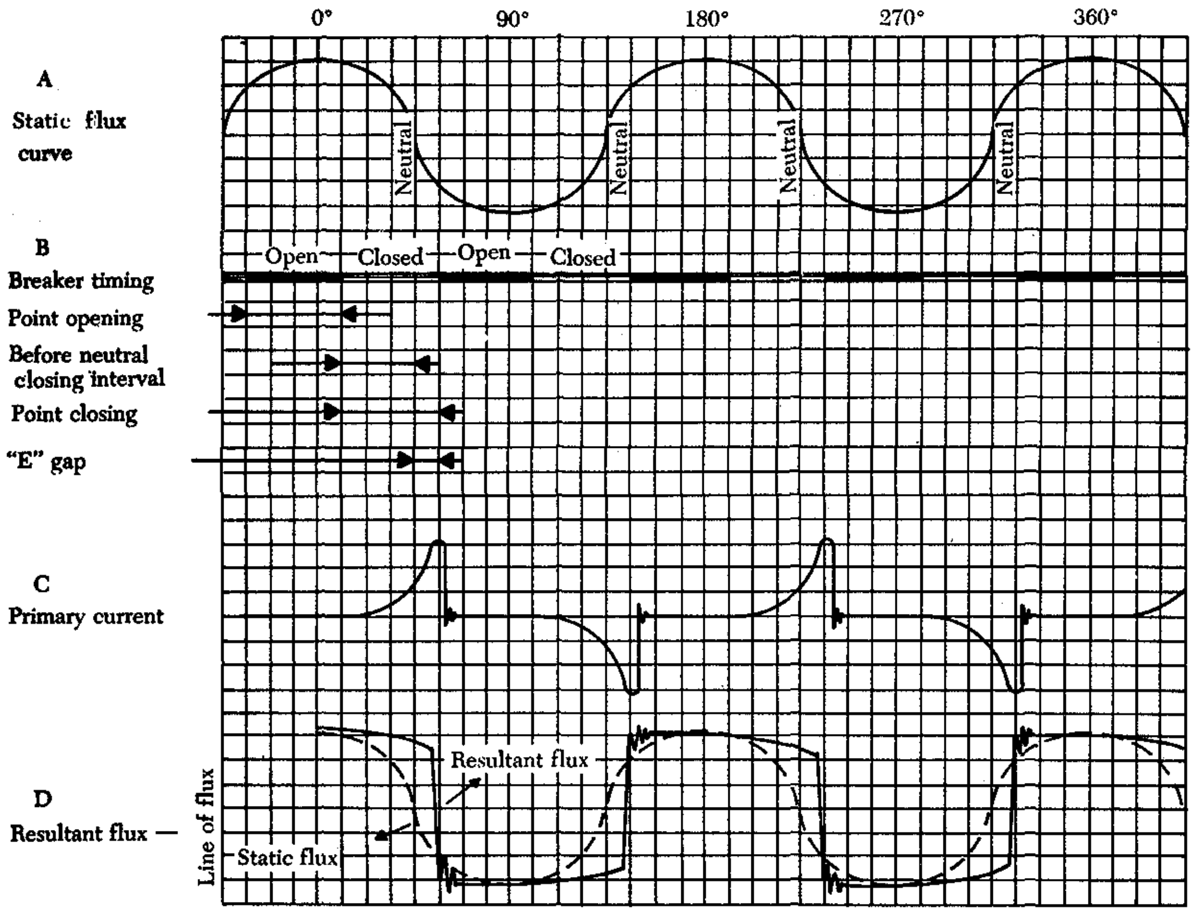


FIGURE 4–6. Magneto flux curves.

a compensated cam, which is designed to operate with a specific engine and has one lobe for each cylinder to be fired by the magneto. The cam lobes are machine ground at unequal intervals to compensate for the top-dead-center variations of each position. A compensated 14-lobe cam, together with a two-, four-, and eight-lobe uncompensated cam, is shown in figure 4–8.

The unequal spacing of the compensated cam lobes, although it provides the same relative piston position for ignition to occur, causes a slight variation of the E-gap position of the rotating magnet and thus a slight variation in the high-voltage impulses generated by the magneto. Since the spacing between each lobe is tailored to a particular cylinder of a particular engine, compensated cams are marked to show the series of the engine, the location of the master rod or rods, the lobe used for magneto timing, the direction of cam rotation, and the E-gap specification in degrees past neutral of magnet rotation. In addition to these markings, a step is cut across the face of the cam, which, when aligned with scribed marks on the magneto housing, places the rotating magnet in the E-gap position for the timing cylinder. Since the breaker points should begin to open when the rotating magnet moves into the E-gap position, alignment of the step on the cam with marks in the housing provides a quick and easy method of establishing the exact E-gap position to check and adjust the breaker points.

Coil Assembly

The magneto coil assembly consists of the soft iron core around which is wound the primary coil and the secondary coil, with the secondary coil wound on top of the primary coil.

The secondary coil is made up of a winding containing approximately 13,000 turns of fine, insulated wire, one end of which is electrically grounded to the primary coil or to the coil core and the other end connected to the distributor rotor. The primary and secondary coils are encased in a nonconducting material of bakelite, hard rubber, or varnished cambric. The whole assembly is then fastened to

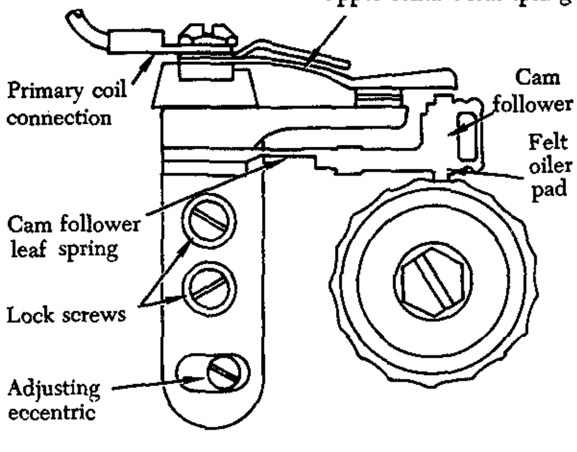


FIGURE 4–7. Pivotless type breaker assembly and cam.

the pole shoes with screws and clamps.

When the primary circuit is closed, the current flow through the primary coil produces magnetic lines of force that cut across the secondary windings, inducing an electromotive force. When the primary circuit is broken, the magnetic field about the primary windings collapses, causing the secondary windings to be cut by the lines of force. The strength of the voltage induced in the secondary windings, when all other factors are constant, is determined by the number of turns of wire. Since most high-tension magnetos have many thousands of turns of wire in the secondary, a very high voltage, often as high as 20,000 volts, is generated in the secondary circuit to jump the air gap of the spark plug in the cylinder.

Distributor

The high voltage induced in the secondary coil is directed to the distributor, which consists of two parts. The revolving part is called a distributor rotor and the stationary part is called a distributor block. The rotating part, which may take the shape of a disk, drum, or finger, is made of a nonconducting material with an embedded conductor. The stationary part consists of a block also made of nonconducting material that contains terminals and terminal receptacles into which the wiring that connects the distributor to the spark plug is attached. In some ignition systems, the distributor assembly is an integral part of the magneto assembly, but others are remotely located and separately driven.

As the magnet moves into the E-gap position for the No. 1 cylinder and the breaker points just separate, the distributor rotor aligns itself with the No. 1 electrode in the distributor block. The secondary voltage induced as the breaker points open enters the rotor where it arcs a small air gap to the No. 1 electrode in the block.

Since the distributor rotates at one-half crankshaft speed on all four-stroke-cycle engines, the distributor block will have as many electrodes as there are engine cylinders, or as many electrodes as cylinders served by the magneto. The electrodes are located circumferentially around the distributor block so that, as the rotor turns, a circuit is completed to a different cylinder and spark plug each time there is alignment between the rotor finger and an electrode in the distributor block. The electrodes of the distributor block are numbered consecutively in the direction of distributor rotor travel (see figure 4–9).

The distributor numbers represent the magneto sparking order rather than the engine cylinder numbers. The distributor electrode marked "1" is connected to the spark plug in the No. 1 cylinder; distributor electrode marked "2" to the second cylinder to be fired; distributor electrode marked "3" to the third cylinder to be fired, and so forth.

Two-lobe cam | Four-lobe cam | Eight-lobe cam | Compensated 14 lobe cam

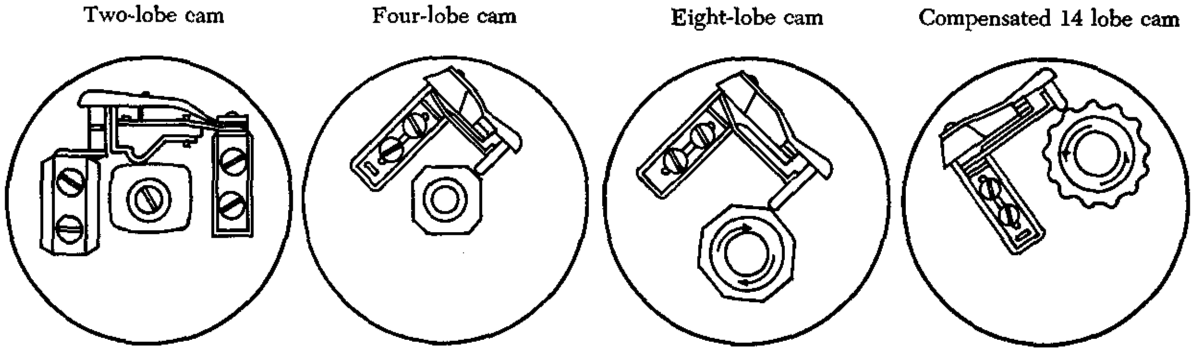


FIGURE 4–8. Typical breaker assemblies.

In figure 4–9 the distributor rotor finger is aligned with the distributor electrode marked "3," which fires the No. 5 cylinder of a 9-cylinder radial engine. Since the firing order of a 9-cylinder radial engine is 1–3–5–7–9–2–4–6–8, the third electrode in the magneto sparking order serves the No. 5 cylinder.

In installations where the magneto and distributor rotors are combined in one assembly, the distributor finger will have been timed at the time of overhaul or manufacture. On engines where the distributor is separate from the magneto, the distributor, as well as the magneto, must be manually adjusted to the timing cylinder to effect proper distribution of the high-voltage impulses.

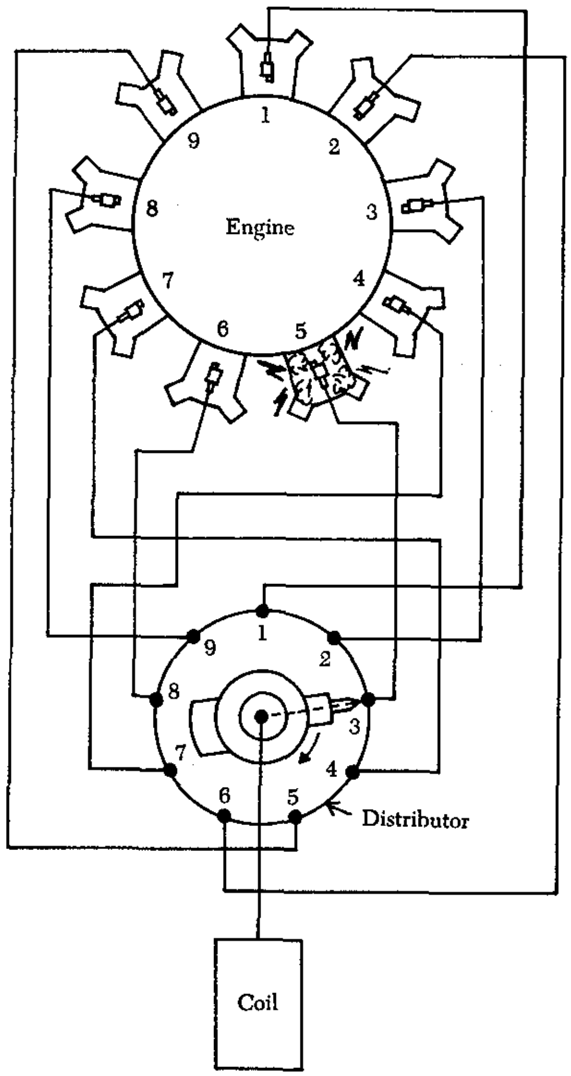


FIGURE 4–9. Relation between distributor terminal numbers and cylinder numbers.

Magneto and Distributor Venting

Since magneto and distributor assemblies are subjected to sudden changes in temperature, the problems of condensation and moisture are considered in the design of these units. Moisture in any form is a good conductor of electricity; and if absorbed by the nonconducting material in the magneto, such as distributor blocks, distributor fingers, and coil cases, it can create a stray electrical conducting path. The high-voltage current that normally arcs across the air gaps of the distributor can flash across a wet insulating surface to ground, or the high-voltage current can be misdirected to some spark plug other than the one that should be fired. This condition is called "flashover" and usually results in cylinder misfiring. For this reason coils, condensers, distributors and distributor rotors are waxed so that moisture on such units will stand in separate beads and not form a complete circuit for flashover.

Flashover can lead to carbon tracking, which appears as a fine pencil-like line on the unit across which flashover occurs. The carbon trail results from the electric spark burning dirt particles which contain hydrocarbon materials. The water in the hydrocarbon material is evaporated during flashover, leaving carbon to form a conducting path for current. And when moisture is no longer present, the spark will continue to follow the track to the ground.

Magnetos cannot be hermetically sealed to prevent moisture from entering a unit because the magneto is subject to pressure and temperature changes in altitude. Thus, adequate drains and proper ventilation reduce the tendency of flashover and carbon tracking. Good magneto circulation also ensures that corrosive gases produced by normal arcing across the distributor air gap are carried away. In some installations, pressurization of various parts of the ignition system is essential to maintain a higher absolute pressure and to eliminate flashover.

Regardless of the method of venting employed, the vent bleeds or valves must be kept free of obstructions. Further, the air circulating through the components of the ignition system must be free of oil, since even minute amounts of oil on ignition parts will result in flashover and carbon tracking.

Ignition Harness

The ignition harness contains an insulated wire for each cylinder that the magneto serves in the engine. One end of each wire is connected to the distributor block and the other end is connected to the proper spark plug. The ignition harness serves a dual purpose. It supports the wires and protects them from damage by engine heat, vibration, or weather. It also serves as a conductor for stray magnetic fields that surround the wires as they momentarily carry high-voltage current. By conducting these magnetic lines of force to the ground, the ignition harness cuts down electrical interference with the aircraft radio and other electrically sensitive equipment. When the radio and other electrical equipment are protected in this manner, the ignition harness wiring is said to be a shield. Without this shielding, radio communication would become virtually impossible.

A common type of ignition harness is a manifold formed to fit around the crankcase of the engine with flexible extensions terminating at each spark plug. A typical high-tension ignition harness is shown in figure 4–10.

Another type is known as the sealed or filled type. A harness of this type has the ignition wires placed in a ring manifold so that the spark plug end of each wire terminates at the manifold outlets. This assembly is then filled with an insulating gelatin which eliminates chafing and moisture condensation. Separate spark plug leads are attached to the manifold outlets. In this manner, it is possible to renew the spark plug end of a lead without replacing the entire length of cable between the spark plug and the distributor.

In installations where the magnetos are mounted on the accessory section of the engine, two large flexible conduits, each containing one-half of the ignition wires, lead aft from the harness to the point where they are connected to the magneto. (See figure 4–11.) In this type of ignition harness, the ignition wires are continuous from the distributor block to the spark plug. If trouble develops, the entire lead must be replaced.

Ignition Switches

All units in an aircraft ignition system are controlled by an ignition switch in the cockpit. The type of switch used varies with the number of engines on the aircraft and the type of magnetos used. All switches, however, turn the system off and on in much the same manner. The ignition switch is different in at least one respect from all other types of switches in that when the ignition switch is in the "off" position, a circuit is completed through the switch to ground. In other electrical switches, the "off" position normally breaks or opens the circuit.

The ignition switch has one terminal connected to the primary electrical circuit between the coil and the breaker contact points. The other terminal of the switch is connected to the aircraft ground (structure). As shown in figure 4–12, two ways to complete the primary circuit are: (1) Through the closed breaker points to ground, or (2) through the closed ignition switch to ground.

In figure 4–12, it can be seen that the primary current will not be interrupted when the breaker contacts open, since there is still a path to ground through the closed (off) ignition switch. Since primary current is not stopped when the contact

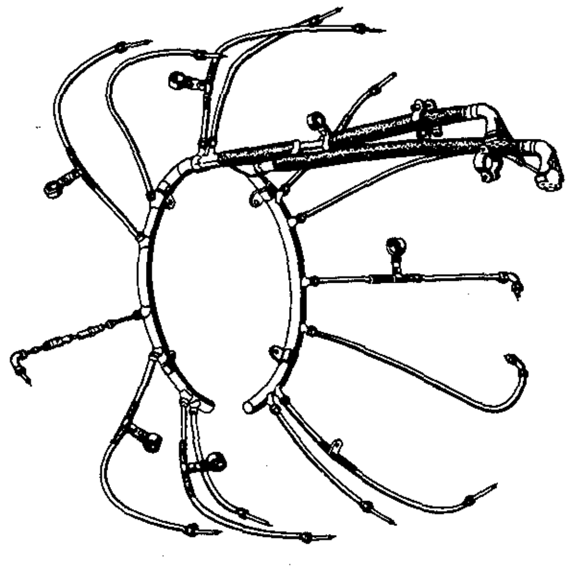


FIGURE 4–10. A high-tension ignition harness.

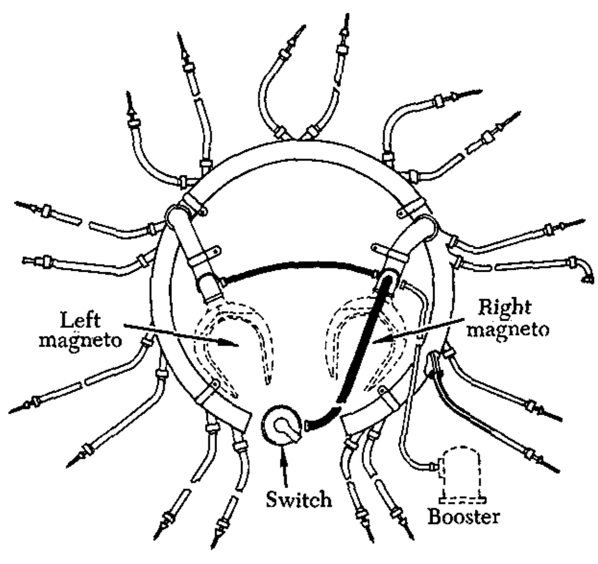


FIGURE 4–11. Accessory-mounted, nine-cylinder engine ignition harness.

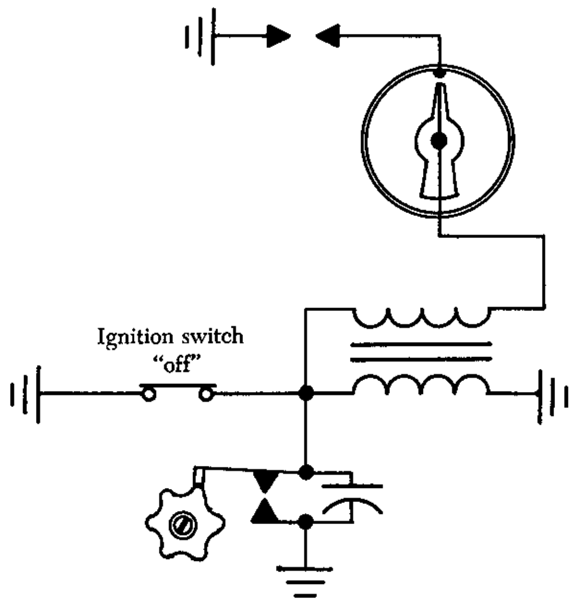


FIGURE 4–12. Typical ignition switch in "off" position.

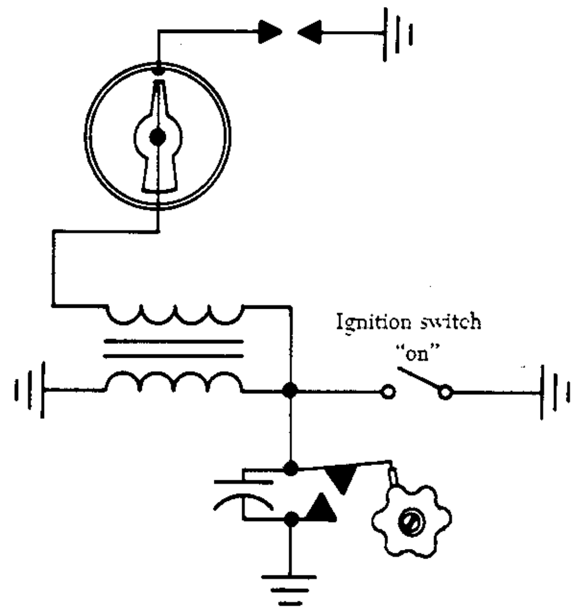


FIGURE 4–13. Typical ignition switch in the "on" position.

points open (figure 4–12), there can be no sudden collapse of the primary coil flux field and no high voltage induced in the secondary coil to fire the spark plug.

As the magnet rotates past the E-gap position, a gradual breakdown of the primary flux field occurs. But that breakdown occurs so slowly that the induced voltage is too low to fire the spark plug. Thus, when the ignition switch is in the "off" position (switch closed), the contact points are as completely short-circuited as if they were removed from the circuit, and the magneto is inoperative.

When the ignition switch is placed in the "on" position (switch open), as shown in figure 4–13, the interruption of primary current and the rapid collapse of the primary coil flux field is once again controlled or triggered by the opening of the breaker contact points. When the ignition switch is in the "on" position, the switch has absolutely no effect on the primary circuit.

Many single-engine aircraft ignition systems employ a dual-magneto system, in which the right magneto supplies the electric spark for the front plugs in each cylinder, and the left magneto fires the rear plugs. One ignition switch is normally used to control both magnetos. An example of this type of switch is shown in figure 4–14.

This switch has four positions: off, left, right, and both. In the "off" position, both magnetos are grounded and thus are inoperative. When the switch is placed in the "left" position, only the left magneto operates; in the "right" position, only the right magneto operates. In the "both" position, both magnetos operate. The "right" and "left" positions are used to check dual-ignition systems, allowing one system to be turned off at a time. Figure 4–14 also refers to the ignition system battery circuit which is discussed with auxiliary ignition units in a following section.

Most twin-engine switches provide the operator with independent control of each magneto in an engine by rotary switches on each side of the ignition switch.

In addition, a toggle master switch is usually incorporated in the switch to ground all the magneto primaries. Thus, in an emergency, all ignition for both engines (four magneto primaries) can be cut off by one movement of this switch. (See figure 4–15.)

Single and Dual High-Tension System Magnetos

High-tension system magnetos used on radial engines are either single- or dual-type magnetos. The single magneto design incorporates the distributor in the housing with the magneto breaker assembly, rotating magnet, and coil. The dual magneto incorporates two magnetos in one housing. One rotating magnet and a cam are common to two sets of breaker points and coils. Two separate distributor units are mounted on the engine apart from the magneto.

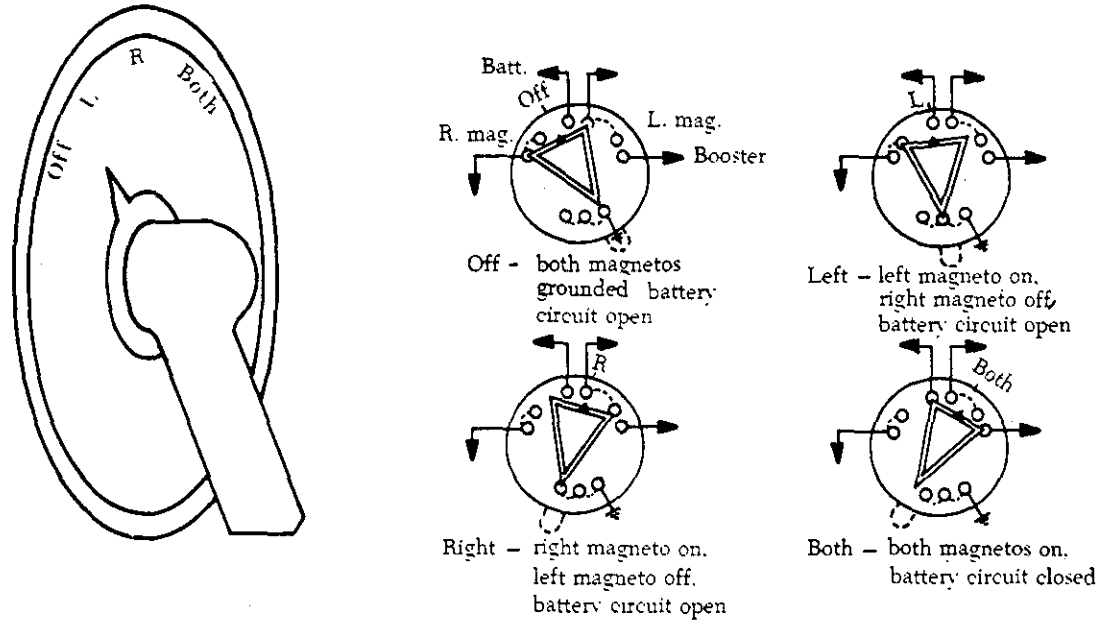


FIGURE 4–14. Switch positions for one ignition switch that controls two magnetos.

Magneto Mounting Systems

Single-type magnetos may be designed for either base-mounting or flange-mounting. Dual-type magnetos are all flange mounted.

Base-mounted magnetos are secured to a mounting bracket on the engine. Flange-mounted magnetos are attached to the engine by a flange around the driven end of the rotating shaft of the magneto. Elongated slots in the mounting flange permit adjustment through a limited range to aid in timing the magneto to the engine.

Low-Tension Magneto System

High tension ignition systems have been in use for more than half a century. Many refinements in the design have been made, but certain underlying problems have remained and others have intensified; such as:

(1) The increase in the number of cylinders per engine.

(2) The requirement that all radio-equipped aircraft have their ignition wires enclosed in metal conduits.

(3) The trend toward all-weather flying.

(4) The increased operation at high altitudes.

To meet these problems, low tension ignition systems were developed.

Electronically, the low-tension system is different from the high-tension system. In the low-tension system, low-voltage is genertaed in the magneto and flows to the primary winding of a transformer coil located near the spark plug. There the voltage is increased to a high voltage by transformer action and conducted to the spark plug by very short high-tension leads. Figure 4–16 is a simplified schematic of a typical low-tension system.

The low-tension system virtually eliminates flashover in both the distributor and the harness because the air gaps within the distributor have been eliminated by the use of a brush-type distributor, and high voltage is present only in short leads between the transformer and spark plug.

Although a certain amount of electrical leakage is characteristic of all ignition systems, it is more pronounced on radio-shielded installations because the metal conduit is at ground potential and close to the ignition wires throughout their entire length. In low-tension systems, however, this leakage is reduced considerably because the current throughout most of the system is transmitted at a low voltage potential. Although the leads between the transformer coils and the spark plugs of a low-tension ignition system are short, they are high-tension (high voltage) conductors, and are subject to the same failures that occur in high-tension systems.

Operation of Low-Tension Ignition System

The magnetic circuit of a typical low-tension magneto system consists of a rotating permanent magnet, the pole shoes, and the coil core (see figure 4–17). The cylindrical magnet is constructed with seven

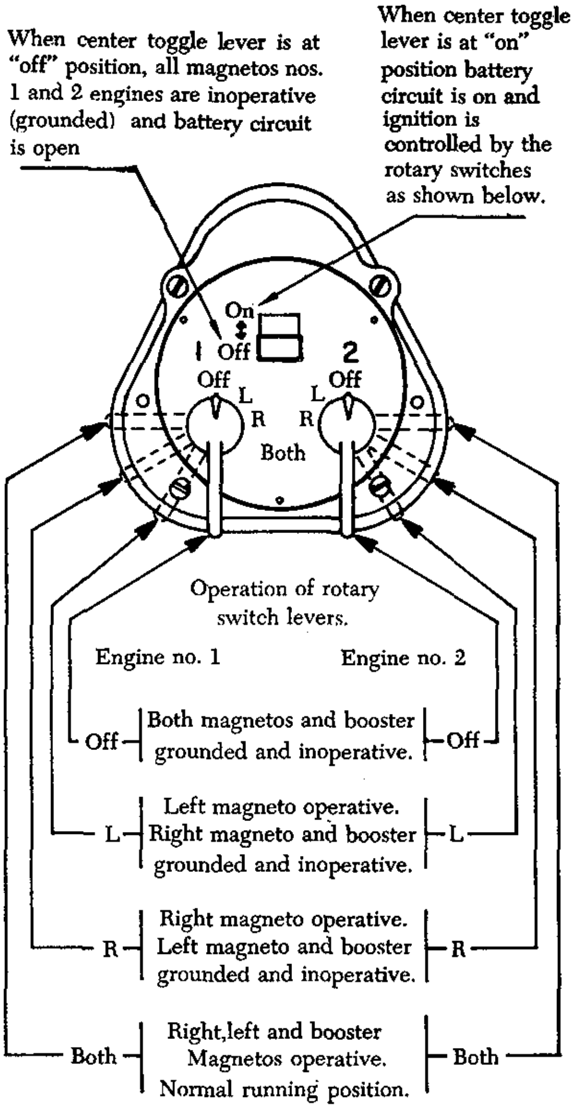


FIGURE 4–15. Magneto switch for a twin-engine aircraft.

pole pieces of one polarity, staggered between seven pole pieces of the opposite polarity.

When the magnet is inserted in the magnetic circuit of figure 4–17 with three of the magnet's north poles perfectly alined with the pole shoes, a maximum static flux flow is produced from right to left in the coil core. When the magnet is rotated clockwise until the adjacent poles align with the pole shoes, flux flow in the coil core will have decreased from a maximum to zero in one direction, and then increased to a maximum in the opposite direction. This constitutes one flux reversal. Fourteen such flux reversals occur during each revolution of the magnet, or seven for each revolution of the engine crankshaft. Voltage production in the magneto coil of a low-tension magneto occurs in the same manner as in the primary magnetic circuit of a high-tension magneto.

Low-Tension System Distributor

Each current pulse produced by the low-tension magneto is directed to the various transformer coils in proper firing order by the brush-type distributor (see figure 4–18).

The distributor assembly consists of a rotating part, called a distributor brush, and a stationary part, called a distributor block. The rotor (A of figure 4–18) has two separate sets of distributor brushes which ride on the three concentric tracks of the distributor block (B of figure 4–18). These tracks are divided into seven segments, each of which is electrically insulated from the other. The outer track consists of a series of alternate long and short electrode sections. The seven long electrode sections of the outer track are electrically dead and serve only to provide a nearly continuous path for distributor brushes to ride. The low-voltage current from the magneto enters the distributor through a wire connected to one of the short electrode sections of the outside track.

Since all the short electrode sections, though separated by electrically dead sections, are connected together internally, each one has magneto coil voltage impressed upon it.

The distributor rotor has two pickup brushes (A of figure 4–18), one at each end of the rotor. The lower pickup brush is electrically connected to the D or C row brush that rides the middle tracks of the distributor block. (Refer to A, B, and C of figure 4–18.)

As the breaker points open, magneto coil current is available to the short electrode sections of the outside track. (See figure 4–19.) At that instant only one of the distributor rotor pickup brushes is on a short electrode section. The other pickup brush is on an electrically insulated (dead) section of the same track. The pickup brush on a short electrode section picks up the magneto coil current and directs it to an electrode section of the middle track. If the magneto is a No. 1 magneto (R-1 or L-1), the middle track will serve the seven cylinders in the "D" row; if it is a No. 2 magneto (R-2 or L-2), this track will serve the seven cylinders of the "C" row (figure 4–18). Similarly, the inside track serves the seven cylinders of the "B" row if it is a No. 1 magneto, or the seven cylinders of the "A"

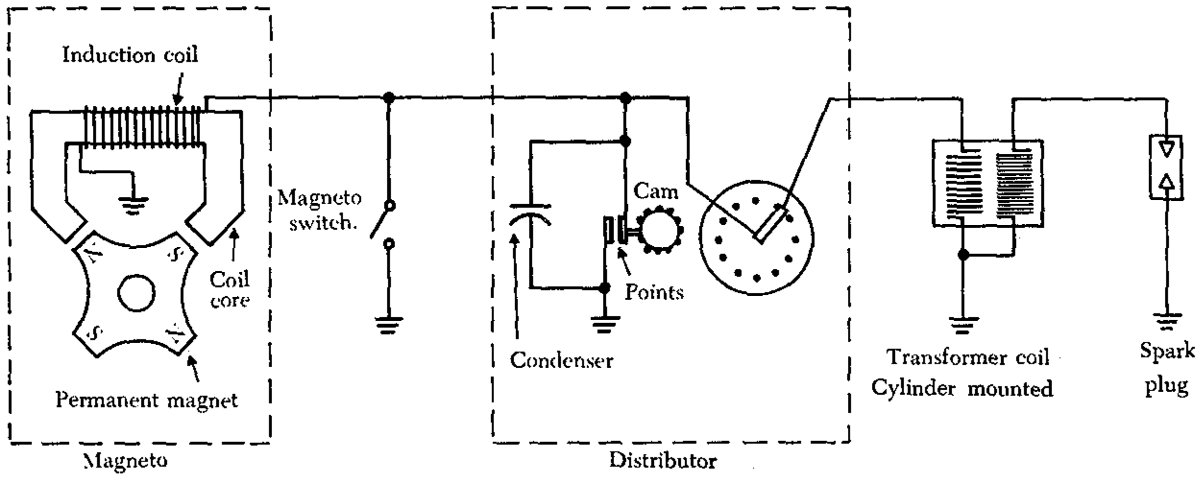


FIGURE 4–16. Simplified low-tension ignition system schematic.

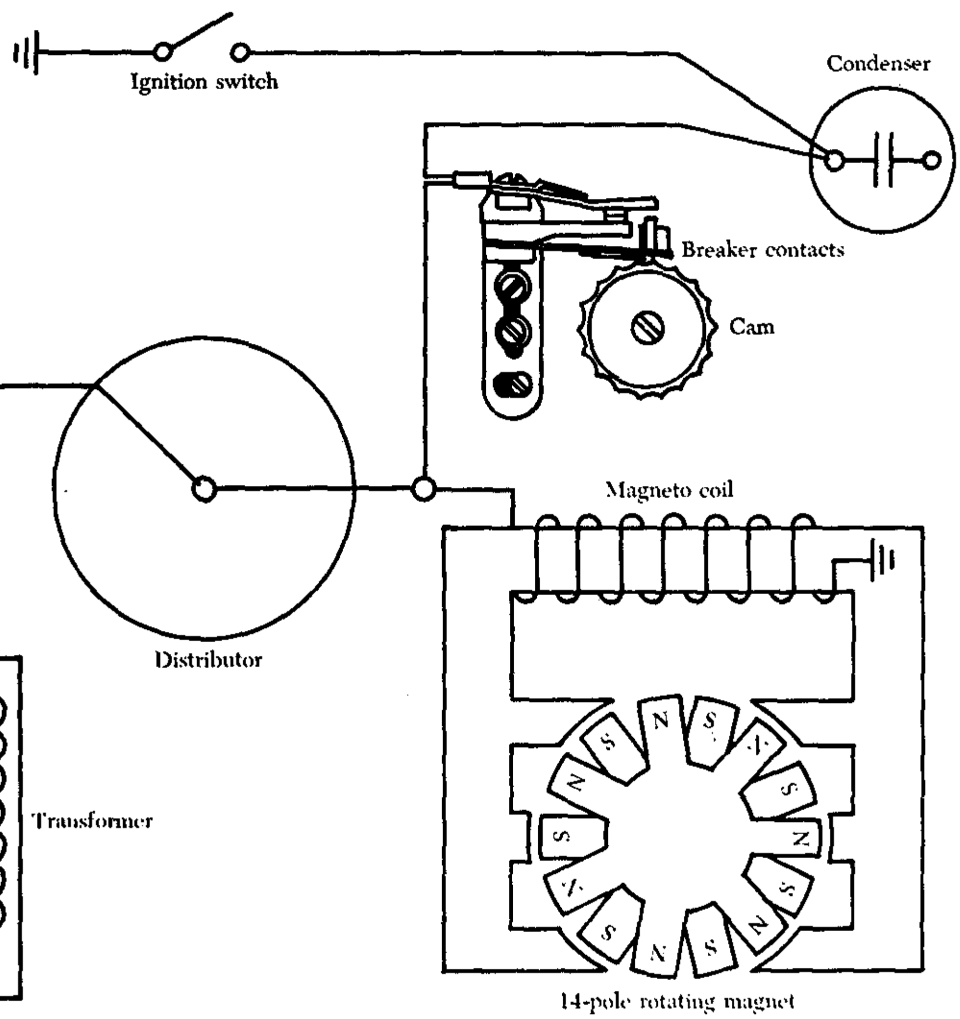
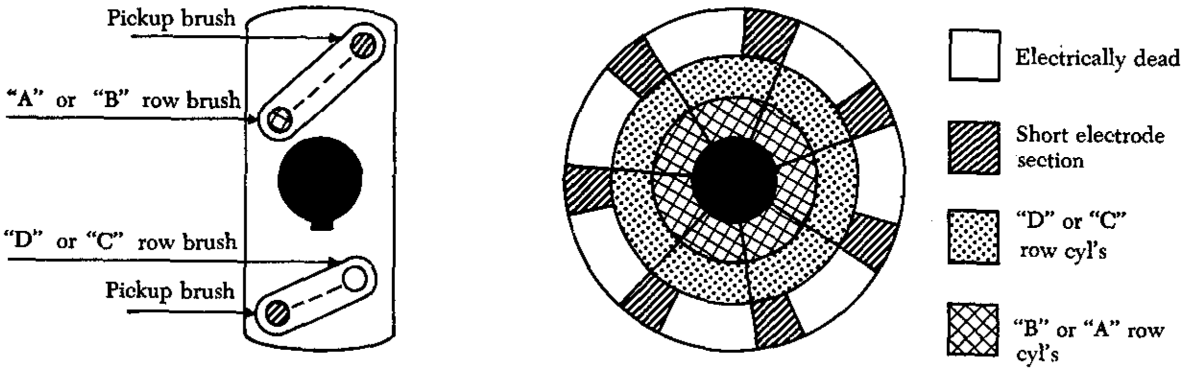


FIGURE 4–17. Low-tension system using a 14-pole rotating magnet.



A B C

FIGURE 4–18. Brush-type distributor for a low-tension magneto system.

row if it is a No. 2 magneto. Since each electrode section of the middle and inside tracks is connected to a separate transformer coil, the rotating distributor brush determines which transformer coil receives the self-induced current surge.

In operation, any one magneto will serve first a cylinder in one row and then a cylinder in the other row. For example, in figure 4–19, the transformer of the fifth cylinder in the magneto sparking order is receiving the self-induced current surge. The next transformer to receive a surge of current in the magneto's sparking order will be the sixth cylinder, which is served by an electrode section on the inside tracks.

The sixth transformer coil in the magneto's sparking order is energized as the pickup brush for the inside track moves clockwise off an electrically insulated section and onto the next short electrode section. Current is then picked off the outside track and directed to the electrode section of the inside track that serves the transformer for the sixth cylinder in sparking order. While the transformer coil for the sixth cylinder is receiving its current surge, the pickup brush for the middle track is on an insulated section of the outside track and does not interfere with the flow of the self-induced current surge. As the distributor brush continues in a clockwise direction, the pickup brush for the inside track moves onto an electrically insulated section. At the same time, the pickup brush for the middle track moves onto a short electrode section to deliver the current surge to the transformer serving the seventh cylinder in the magneto sparking order.

The relatively low self-induced current leaves the distributor through the wires leading to the transformers. The wires are connected to the circular ignition manifold by a plug connector. For this

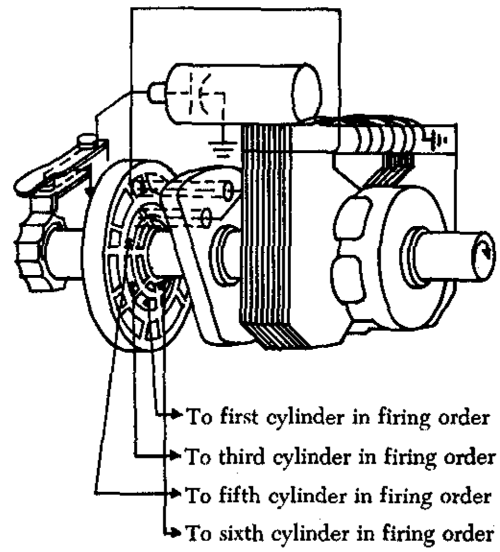


FIGURE 4–19. Brush-type distributor operation.

magneto system there are 60 cables within the circular ignition manifold. Four cables (one for each of the four magnetos) run from the ignition switch to the terminal in the cannon plug connected to the ignition switch wire. The remaining 56 cables connect the distributor electrode sections of the inside and middle tracks of four magnetos to the primary coils of the spark plug transformers. The current from the secondary coil of the transformer is conducted to the spark plug by a short, high-tension shielded cable.

Low-tension magnetos are turned off and on in the same manner that high-tension systems are controlled, i.e., by a switch connected to the ground wire of the magneto coil circuit. When the switch is closed (off position), a direct low-resistance path to ground is made available to the magneto coil whether the breaker points are open or closed.

Since the closed ignition switch provides a low-resistance path to ground, magneto coil current is not directed to the primary coil of the transformer. Instead, current is short-circuited by way of the closed ignition switch.

AUXILIARY IGNITION UNITS

During engine starting, the output of either a high- or low-tension magneto is low because the cranking speed of the engine is low. This is understandable when the factors that determine the amount of voltage induced in a circuit are considered.

To increase the value of an induced voltage, the strength of the magnetic field must be increased by using a stronger magnet, by increasing the number of turns in the coil, or by increasing the rate of relative motion between the magnet and the conductor.

Since the strength of the rotating magnet and the number of turns in the coil are constant factors in both high- and low-tension magneto ignition systems, the voltage produced depends upon the speed at which the rotating magnet is turned. When the engine is being cranked for starting, the magnet is rotated at about 80 r.p.m. Since the value of the induced voltage is so low, a spark may not jump the spark plug gap. Thus, to facilitate engine starting, an auxiliary device is connected to the magneto to provide a high ignition voltage.

Ordinarily, such auxiliary ignition units are energized by the battery and connected to the right magneto or distributor. Reciprocating engine starting systems normally include one of the following types of auxiliary starting systems: booster coil, induction vibrator (sometimes called starting vibrator), impulse coupling, or other specialized retard breaker and vibrator starting systems.

Booster Coil

The booster coil assembly (figure 4–20) consists of two coils wound on a soft iron core, a set of contact points, and a condenser. The primary winding has one end grounded at the internal grounding strip and its other end connected to the moving contact point. The stationary contact is fitted with a terminal to which battery voltage is applied when the magneto switch is placed in the "start" position, or automatically applied when the starter is engaged. The secondary winding, which contains several times as many turns as the primary coil, has one end grounded at the internal grounding strip and the other terminated at a high-tension terminal. The high-tension terminal is connected to an electrode in the distributor by an ignition cable.

Since the regular distributor terminal is grounded through the primary or secondary coil of a high-tension magneto, the high voltage furnished by the booster coil must be distributed by a separate circuit in the distributor rotor. This is accomplished by using two electrodes in one distributor rotor. The main electrode or "finger" carries the magneto output voltage, and the auxiliary electrode distributes only the output of the booster coil. The auxiliary electrode is always located so that it trails the main electrode, thus retarding the spark during the starting period.

Figure 4–21 illustrates, in schematic form, the booster coil components shown in figure 4–20. In operation, battery voltage is applied to the positive (+) terminal of the booster coil through the start switch. This causes current to flow through the closed contact points (figure 4–21) to the primary coil and ground. Current flow through the primary coil sets up a magnetic field about the coil which magnetizes the coil core. As the core is magnetized, it attracts the movable contact point, which is normally held against the stationary contact point by a spring.

As the movable contact point is pulled toward the iron core, the primary circuit is broken, collapsing the magnetic field that extended about the coil core. Since the coil core acts as an electromagnet only when current flows in the primary coil, it loses its magnetism as soon as the primary coil circuit is broken. This permits the action of the spring to close the contact points and again complete the primary coil circuit. This, in turn, re-magnetizes the coil core, and again attracts the movable contact point, which again opens the primary coil circuit. This action causes the movable contact point to vibrate rapidly, as long as the start switch is held in the closed (on) position. The result of this action is a continuously expanding and collapsing magnetic field that links the secondary coil of the booster coil. With several times as many turns in the secondary as in the primary, the induced voltage that results from lines of force linking the secondary is high enough to furnish ignition for the engine.

The condenser (figure 4–21), which is connected across the contact points, has an important function in this circuit. As current flow in the primary coil is interrupted by the opening of the contact points, the high self-induced voltage that accompanies each collapse of the primary magnetic field surges into the condenser. Without a condenser, an arc would

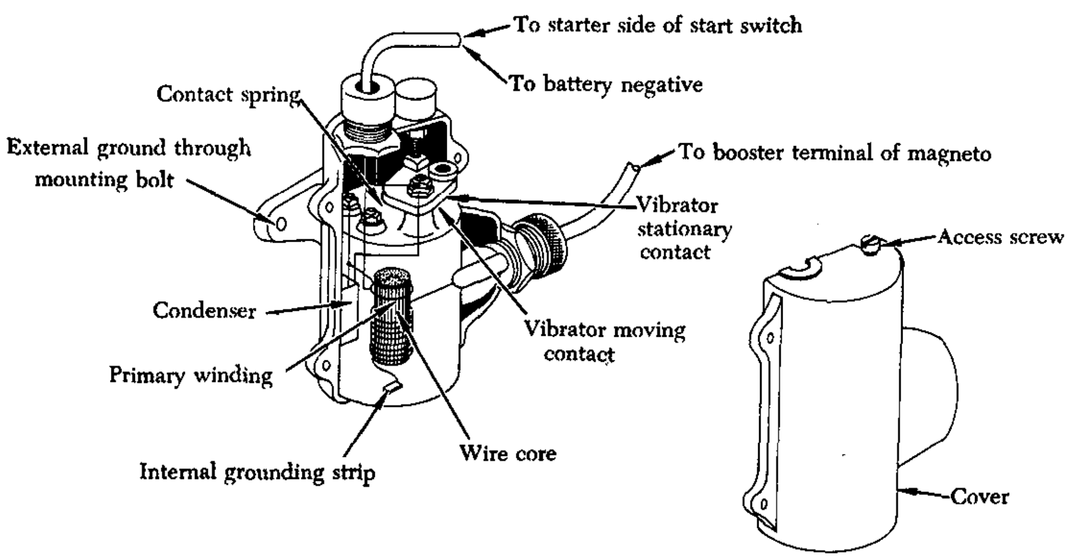


FIGURE 4–20. Booster coil.

jump across the points with each collapse of the magnetic field. This would burn and pit the contact points and greatly reduce the voltage output of the booster coil.

Induction Vibrator

The induction vibrator (or starting vibrator) shown in figure 4–22 consists essentially of an electrically operated vibrator, a condenser, and a relay. These units are mounted on a base plate and enclosed in a metal case.

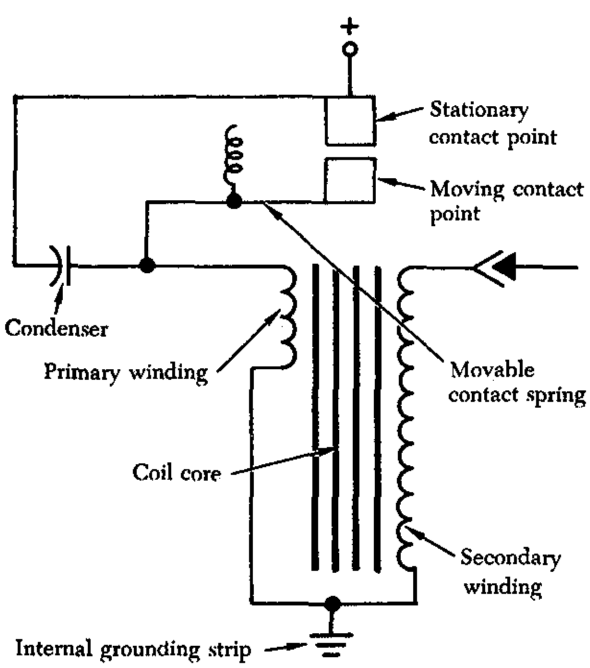


FIGURE 4–21. Booster coil schematic.

The starting vibrator, unlike the booster coil, does not produce the high ignition voltage within itself. The function of this starting vibrator is to change the direct current of the battery into a pulsating direct current and deliver it to the primary coil of the magneto. It also serves as a relay for disconnecting the auxiliary circuit when it is not in use.

As shown in figure 4–22, the positive terminal of the starting vibrator is connected into the starter meshing solenoid circuit. Closing this switch energizes the meshing solenoid and causes current to flow through the relay coil to ground. At the same time, current also flows through the vibrator coil and its contact points. Since current flow through the relay coil establishes a magnetic field that attracts and closes the relay points, the vibrator circuit is now complete to the magneto. The electrical path that battery current takes in the magneto is determined by the position of the primary breaker contact points; if the points are closed, current flows through them to ground; if the points are open, current flows through the primary coil to ground.

Current flow in the vibrator coil sets up a magnetic field that attracts and opens the vibrator points. When the vibrator points open, current flow in the coil stops, and the magnetic field that attracted the movable vibrator contact point disappears. This allows the vibrator points to close and again permits battery current to flow in the vibrator coil. This completes a cycle of operation. The cycle, however, occurs many times per second, so rapidly, in fact, that the vibrator points produce an audible buzz.

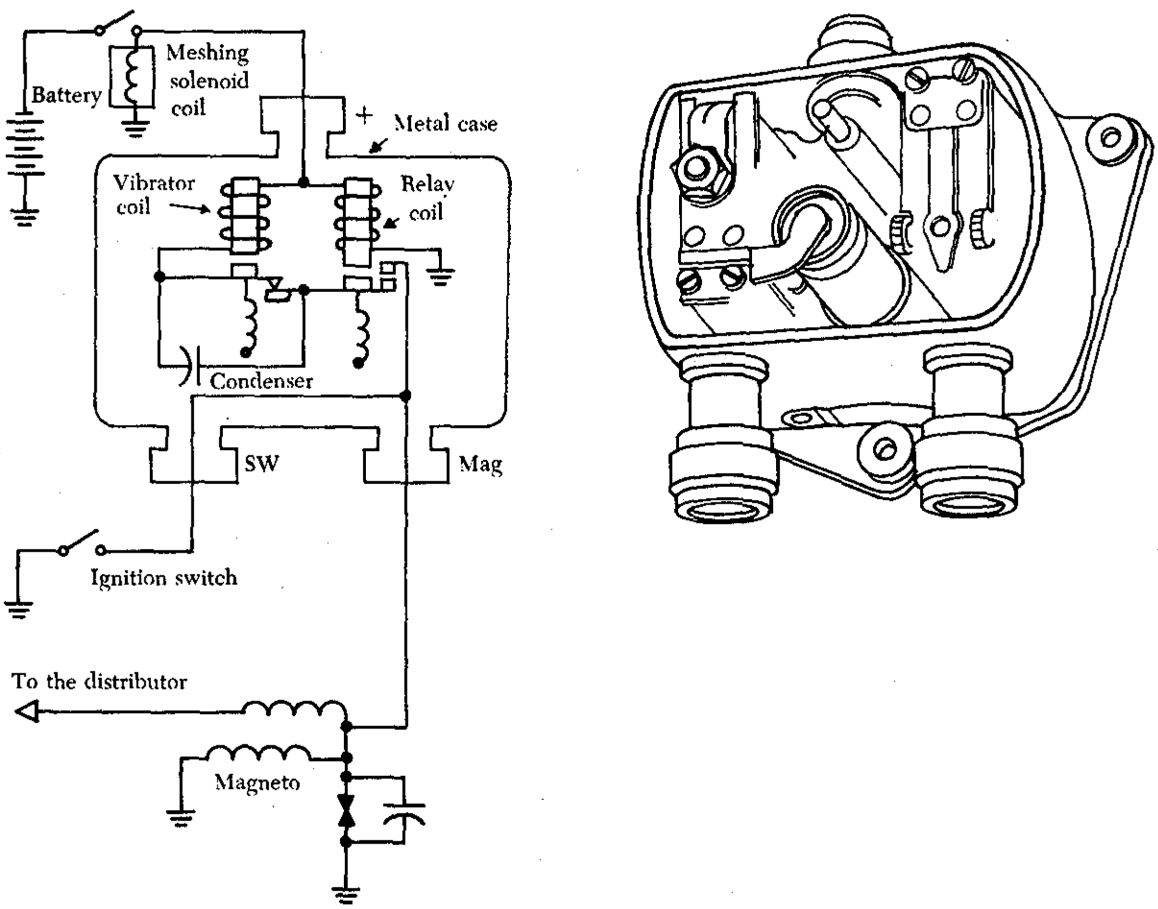


FIGURE 4–22. Induction vibrator.

Each time the vibrator points close, current flows to the magneto. If the primary breaker contact points are closed, almost all the battery current passes to ground through them, and very little passes through the primary coil. Thus, no appreciable change in flux in the primary coil occurs. When the magneto breaker contact points open, current that had been flowing through the breaker points is now directed through the primary coil to ground. Since this current is being interrupted many times per second, the resulting magnetic field is building and collapsing across the primary and secondary coils of the magneto many times per second.

The rapid successions of separate voltages induced in the secondary coil will produce a "shower" of sparks across the selected spark plug air gap. The succession of separate voltages is distributed through the main distributor finger to the various spark plugs because the breaker contact points trigger the sparks just as they do when the magneto is generating its own voltage. Ignition systems that use an induction vibrator have no provision for retarding the spark; hence they will not have a trailing auxiliary distributor electrode.

When starting an engine equipped with an induction vibrator, the ignition switch must be kept in the "off" position until the starter has cranked the propeller through one revolution. Then, while the propeller is still turning, the ignition switch should be turned to the "on" (or both) position. If this precaution is not observed, engine kickback will probably result from ignition before top center and low cranking r.p.m. After the propeller has completed at least one revolution, it will have gained sufficient momentum to prevent kickback.

As soon as the engine begins firing and the starter switch is released, the electric circuit from the battery to the induction vibrator is opened. When battery current is cut off from the induction vibrator, the relay points open and break the connection between the induction vibrator and the magneto. This connection must be broken to prevent the magneto from being grounded out at the relay coil. If the relay points of the induction vibrator did not open when battery current was cut off, primary current in the magneto would not be interrupted when the breaker points open; instead, primary current would flow back through the relay and vibrator points of the induction vibrator and then to ground through the relay coil. In this event, the magneto would be just as inoperative as though the ignition switch were placed in the "off" position.

Impulse Coupling

Engines having a small number of cylinders are sometimes equipped with what is known as an impulse coupling. This is a unit which will, at the time of spark production, give one of the magnetos attached to the engine a brief acceleration and produce a hot spark for starting. This device consists of small flyweights and spring assemblies located within the housing which attaches the magneto to the accessory shaft.

The magneto is flexibly connected through the impulse coupling by means of the spring so that at low speed the magneto is temporarily held while the accessory shaft is rotated until the pistons reach approximately a top center position. At this point the magneto is released and the spring kicks back to its original position, resulting in a quick twist of the rotating magnet. This, being equivalent to high-speed magneto rotation, produces a hot spark.

After the engine is started and the magneto reaches a speed at which it furnishes sufficient current, the flyweights in the coupling fly outward due to centrifugal force and lock the two coupling members together. That makes it a solid unit, returning the magneto to a normal timing position relative to the engine. The presence of an impulse coupling is identified by a sharp clicking noise as the crankshaft is turned at cranking speed past top center on each cylinder.

Use of the impulse coupling produces impact forces on the magneto, the engine drive parts, and various parts of the coupling unit. Often the flyweights become magnetized and do not engage the stop pins; congealed oil on the flyweights during cold weather may produce the same results. Another disadvantage of the impulse coupling is that it can produce only one spark for each firing cycle of the cylinder. This is a disadvantage especially during adverse starting conditions.

High-Tension Retard Breaker Vibrator

The retard breaker magneto and starting vibrator system is used as part of the high-tension system on many small aircraft. Designed for four- and six-cylinder ignition systems, the retard breaker magneto eliminates the need for the impulse coupling in light aircraft. This system uses an additional breaker to obtain retarded sparks for starting. The starting vibrator is also adaptable to many helicopter ignition systems. A schematic diagram of an ignition system using the retard breaker magneto and starting vibrator concept is shown in figure 4–23.

With the magneto switch in the "both" position (figure 4–23) and the starter switch S1 in the "on" position, starter solenoid L3 and coil L1 are energized, closing relay contacts R4, R1, R2, and R3. R3 connects the right magneto to ground, keeping it inoperative during starting operation. Electrical current flows from the battery through R1, vibrator points V1, coil L2, through both the retard breaker points, and through R2 and the main breaker points of the left magneto to ground.

The energized coil L2 opens vibrator points V1, interrupting the current flow through L2. The magnetic field about L2 collapses, and vibrator points V1 close again. Once more current flows through L2, and again V1 vibrator points open. This process is repeated continuously, and the interrupted battery current flows to ground through the main and retard breaker points of the left magneto.

Since relay R4 is closed, the starter is energized and the engine crankshaft is rotated. When the engine reaches its normal advance firing position, the main breaker points of the left magneto open. The interrupted surges of current from the vibrator can still find a path to ground through the retard breaker points, which do not open until the retarded firing position of the engine is reached. At this point in crankshaft travel, the retard points open. Since the main breaker points are still open, the magneto primary coil is no longer shorted, and current produces a magnetic field around T1.

Each time the vibrator points V1 open, current flow through V1 is interrupted. The collapsing field about T1 cuts through the magneto coil secondary and induces a high-voltage surge of energy used to fire the spark plug. Since the V1 points are opening and closing rapidly and continuously, a shower of sparks is furnished to the cylinders when both the main and retard breaker points are open.

After the engine begins to accelerate, the manual starter switch is released, causing L1 and L3 to

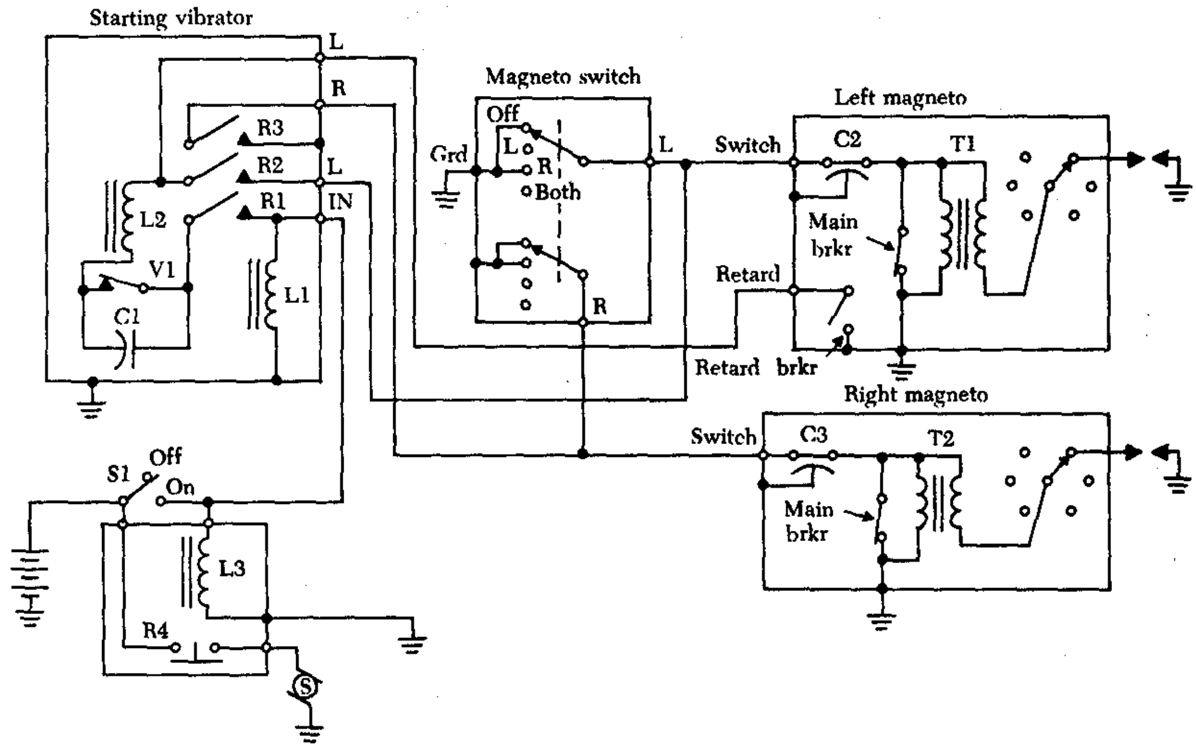


FIGURE 4–23. High-tension, retard breaker magneto and starting vibrator circuit.

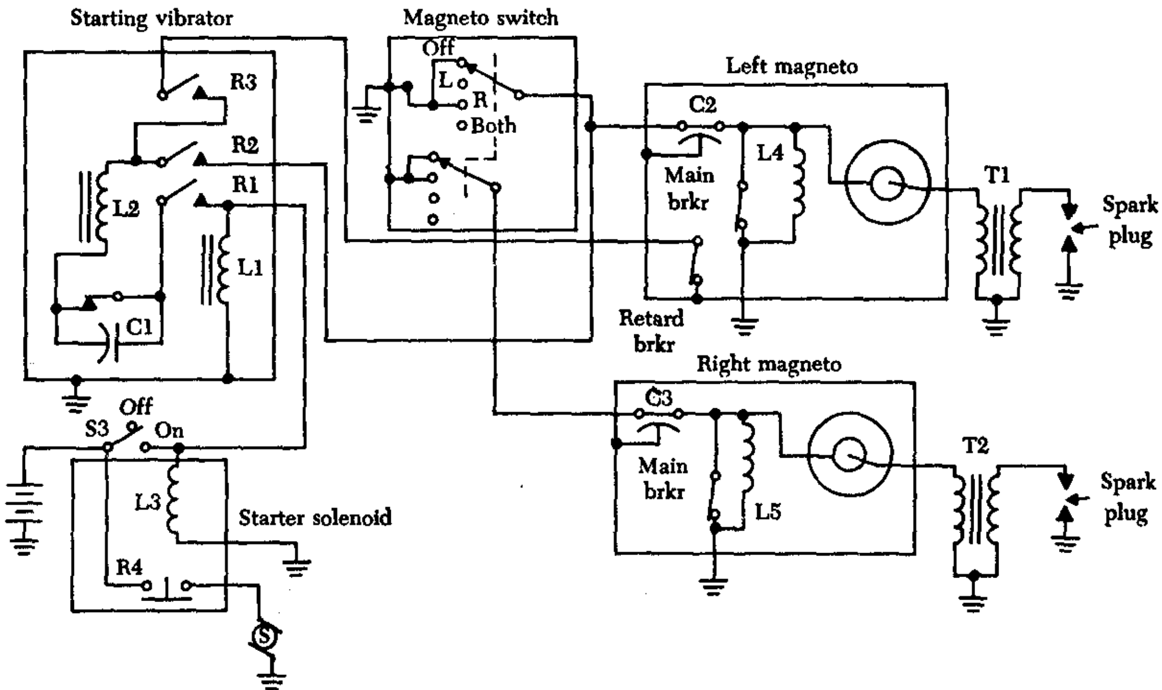


FIGURE 4–24. Low-tension retard breaker magneto and starting vibrator circuit.

become de-energized. This action causes both the vibrator and retard breaker circuits to become inoperative. It also opens relay contact R3, which removes the ground from the right magneto. Both magnetos now fire at the advance (normal running) piston position.

Low-Tension Retard Breaker Vibrator

The system, designed for four- and six-cylinder light aircraft eliminates the disadvantages of both impulse coupling and high-tension ignition systems. A typical system, shown in figure 4–24, consists of a retard breaker magneto, a single breaker magneto, a starting vibrator, transformer coils, and a starter and ignition switch.

To operate the system shown in figure 4–24, place the starter switch S3 in the "on" position. This energizes starter solenoid L3 and coil L1, closing relay contacts R1, R2, R3, and R4. With the magneto switch in the "L" position, current flows through R1, the vibrator points, L2, R2, and through the main breaker points to ground. Current also flows through R3 and the retard breaker points to ground. Current through L2 builds up a magnetic field which opens the vibrator points. Then the current stops flowing through L2, reclosing the points. These surges of current flow through both the retard and main breaker points to ground.

Since the starter switch is closed, the engine crankshaft is turning. When it has turned to the normal advance (running) ignition position, the main breaker points of the magneto open. But current still flows to ground through the closed retard breaker points. As the engine continues to turn, the retard ignition position is reached, and the retard breaker points open. Since the main breaker points are still open, current must flow to ground through coil L4, producing a magnetic field around the coil L4.

As the engine continues to turn, the vibrator breaker points open, collapsing the L4 magnetic field through T1 primary, inducing a high voltage in the secondary of T1 to fire the spark plug.

When the engine fires, the starter switch is released, deenergizing L1 and L3. This opens the vibrator circuit and retard breaker points circuit. The ignition switch is then turned to the "both" position, permitting the right magneto to operate in time with the left magneto.

SPARK PLUGS

The function of the spark plug in an ignition system is to conduct a short impulse of high voltage current through the wall of the combustion chamber. Inside the combustion chamber it provides an air gap across which this impulse can produce an electric spark to ignite the fuel/air charge. While the aircraft spark plug is simple in construction and operation, it is nevertheless the direct or indirect cause of a great many malfunctions in aircraft engines. But spark plugs provide a great deal of trouble-free operation, considering the adverse conditions under which they operate.

In each cylinder of an engine operating at 2,100 r.p.m., approximately 17 separate and distinct high-voltage sparks bridge the air gap of a single spark plug each second. This appears to the naked eye as a continuous fire searing the spark plug electrodes at temperatures of over 3,000° F. At the same time the spark plug is subjected to gas pressures as high as 2,000 p.s.i. and electrical pressure as high as 15,000 volts.

The three main components of a spark plug (figure 4–25) are the electrode, insulator, and outer shell. The outer shell, threaded to fit into the cylinder, is usually made of finely machined steel and is often plated to prevent corrosion from engine gases and possible thread seizure. Close-tolerance screw threads and a copper gasket prevent cylinder gas pressure from escaping around the plug. Pressure that might escape through the plug is retained by inner seals between the outer metal shell and the insulator, and between the insulator and the center electrode assembly.

The insulator provides a protective core around the electrode. In addition to affording electrical insulation, the ceramic insulator core also transfers heat from the ceramic tip, or nose, to the cylinder.

The types of spark plugs used in different engines

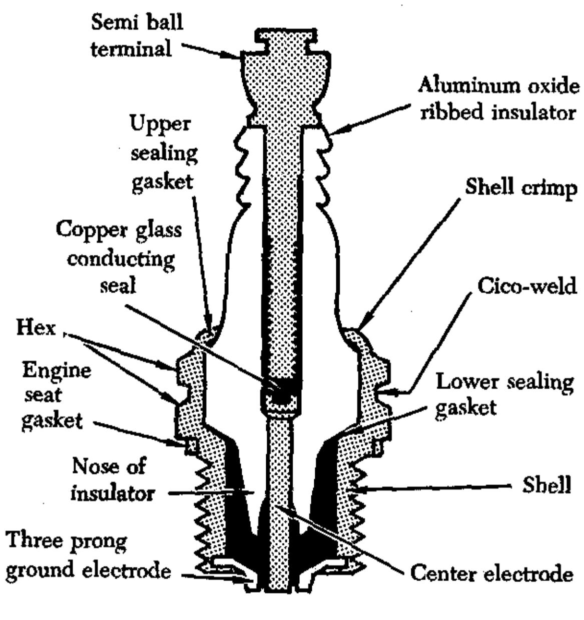


FIGURE 4–25. A typical spark plug.

vary in respect to heat, range, reach, thread size, or other characteristics of the installation requirements of different engines.

The heat range of a spark plug is a measure of its ability to transfer heat to the cylinder head. The plug must operate hot enough to burn off deposits which can cause fouling, yet remain cool enough to prevent a preignition condition. The length of the nose core is the principal factor in establishing the plug's heat range. "Hot" plugs have a long insulator nose that creates a long heat transfer path, whereas "cold" plugs have a relatively short insulator to provide a rapid transfer of heat to the cylinder head (figure 4–26).

If an engine were operated at only one speed, spark plug design would be greatly simplified. Because flight demands impose different loads on the engine, spark plugs must be designed to operate as hot as possible at slow speeds and light loads, and as cool as possible at cruise and takeoff power.

The choice of spark plugs to be used in a specific aircraft engine is determined by the engine manufacturer after extensive tests. When an engine is certificated to use hot or cold spark plugs, the plug used is determined by how the engine is to be operated.

A spark plug with the proper reach (figure 4–27) will ensure that the electrode end inside the cylinder is in the best position to achieve ignition. The spark plug reach is the threaded portion inserted in the spark plug bushing of the cylinder. Spark plug seizure and/or improper combustion within the cylinder will probably occur if a plug with the wrong reach is used.

RECIPROCATING ENGINE IGNITION SYSTEM MAINTENANCE AND INSPECTION

An aircraft's ignition system is the result of

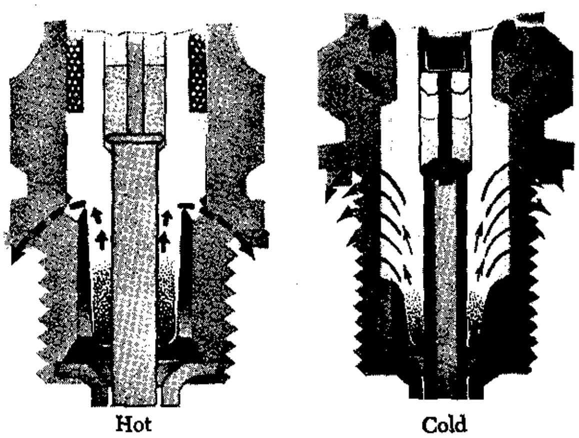


FIGURE 4–26. Hot and cold spark plugs.

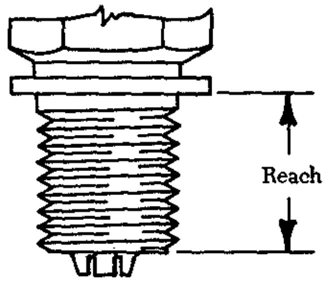


FIGURE 4–27. Spark plug reach.

careful design and thorough testing. In all probability the ignition system will provide good, dependable service, provided it is maintained properly. However, difficulties can occur which will affect ignition system performance. The most common of these maintenance difficulties, together with the most generally accepted methods of ignition inspection, are discussed in this section.

Breakdown of insulating materials, burning and pitting of breaker points, and short circuits or broken electrical connections are not uncommon. These defects must be found and corrected.

Less common are the irregularities that involve human error. For example, ignition timing requires precise adjustment and painstaking care so that the following four conditions occur at the same instant:

(1) The piston in the No. 1 cylinder must be in a position a prescribed number of degrees before top dead center on the compression stroke.

(2) The rotating magnet of the magneto must be in the E-gap position.

(3) The breaker points must be just opening on the No. 1 cam lobe.

(4) The distributor finger must be aligned with the electrode serving the No. 1 cylinder.

If one of these conditions is out of synchronization with any of the others, the ignition system is said to be "out of time."

When ignition in the cylinder occurs before the optimum crankshaft position is reached, the timing is said to be "early." If ignition occurs too early, the piston rising in the cylinder will be opposed by the full force of combustion. This condition results in a loss of engine power, overheating, and possible detonation and preignition. If ignition occurs at a time after the optimum crankshaft position is reached, the ignition timing is said to be "late." If it occurs too late, not enough time will be allowed to consume the fuel/air charge, and combustion will be incomplete. As a result, the engine loses power, and a greater throttle opening will be required to carry a given propeller load.

More common irregularities are those caused by moisture forming on different parts of the ignition system. Moisture can enter ignition system units through cracks or loose covers, or it can result from condensation. "Breathing," a situation which occurs during the readjustment of the system from low to high atmospheric pressure, can result in drawing in moisture-laden air. Ordinarily the heat of the engine is sufficient to evaporate this moisture, but occasionally the moist air condenses as the engine cools. The result is an appreciable moisture accumulation, which causes the insulation materials to lose their electrical resistance. A slight amount of moisture contamination may cause reduction in magneto output by short-circuiting to ground a part of the high-voltage current intended for the spark plug. If the moisture accumulation is appreciable, the entire magneto output may be dissipated to ground by way of flashover and carbon tracking. Moisture accumulation during flight is extremely rare, because the high operating temperature of the system is effective in preventing condensation; hence difficulties from this cause will probably be more evident during ground operation.

Aircraft spark plugs take the blame unjustly for many ignition system malfunctions. Spark plugs are often diagnosed as being faulty when the real malfunction exists in some other system. Malfunctioning of the carburetor, poor fuel distribution, too much valve overlap, leaking primer system, or poor idle speed and mixture settings will show symptoms that are the same as those for faulty ignition. Unfortunately, many of these conditions can be temporarily improved by a spark plug change, but the trouble will recur in a short time because the real cause of the malfunction has not been eliminated. A thorough understanding of the various engine systems, along with meticulous inspection and good maintenance methods, can substantially reduce such errors.

MAGNETO IGNITION TIMING DEVICES

When the many opportunities for errors in timing the ignition system to the engine are considered, the emphasis placed on the correct use of timing devices that follows is easily justified. Errors can easily occur in positioning the piston in the timing cylinder. It can be placed at the wrong crankshaft degree, or at the correct crankshaft degree but on the wrong stroke. When positioning the magneto's rotating magnet, an error can be made by not removing the backlash in the gear train. The breaker point assemblies may not be perfectly synchronized, or they may be synchronized but not opening at E-gap. Any other errors will alter the final spark timing. Because of the many chances for error, timing devices have been developed to ensure more consistent and accurate timing methods.

Built-in Engine Timing Reference Marks

Most reciprocating engines have timing reference marks built into the engine. On an engine which has no propeller reduction gear, the timing mark will normally be on the propeller flange edge (figure 4–28). The TC (top center) mark stamped on the edge will align with the crankcase split line below the crankshaft when the No. 1 piston is at top dead center. Other flange marks indicate degrees before top center. On some engines there are degree markings on the propeller reduction drive gear. To time these engines, the plug provided on the exterior of the reduction gear housing must be removed to view the timing marks. On other engines, the timing marks are on a crankshaft flange and can be viewed by removing a plug from the crankcase. In every case, the engine manufac-

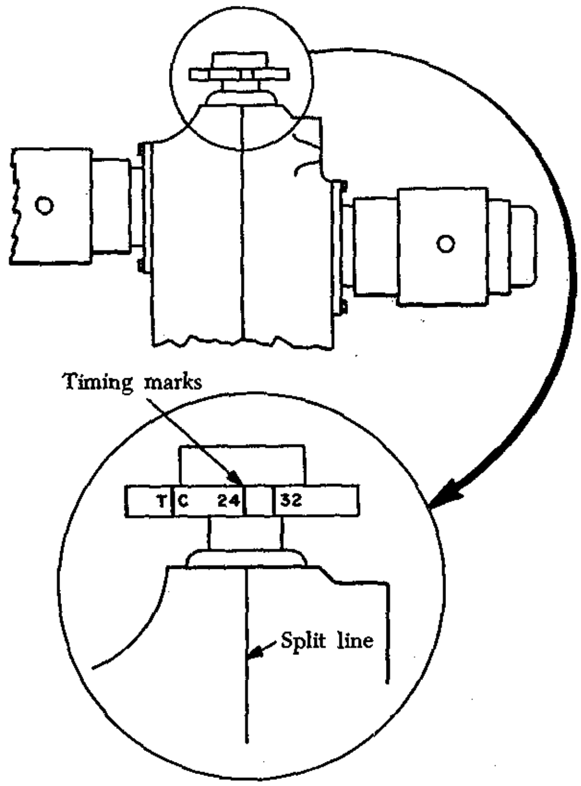


FIGURE 4–28. Propeller flange timing marks.

turer's instructions will give the location of built-in timing reference marks.

In using built-in timing marks (figure 4–29) to position the crankshaft, be sure to sight straight across the stationary pointer or mark on the nose section, the propeller shaft, crankshaft flange, or bell gear. Sighting at an angle will result in an error in positioning the crankshaft.

While many engines have timing reference marks, they leave something to be desired. The main drawback is the backlash factor. The amount of backlash in any system of gears will vary between installations and will even vary between two separate checks on the same piece of equipment. This results because there is no way of imposing a load on the gear train in a direction opposite the direction of crankshaft rotation. Another unfavorable aspect in the use of timing marks on the reduction gear is the small error that exists when sighting down the reference mark to the timing mark inside the housing on the reduction gear. Because there is depth between the two reference marks, each mechanic must have his eye in exactly the same plane. If not, each man will select a different crankshaft position for ignition timing.

Timing Disks

The timing disk is a more accurate crankshaft positioning device than the timing reference marks. This device consists of a disk and a pointer mechanism mounted on an engine-driven accessory or its mounting pad. The pointer, which is indirectly connected to the accessory drive, indicates the number of degrees of crankshaft travel on the disk. The disk is marked off in degrees of crankshaft travel. By applying a slight torque to the accessory drive gear in a direction opposite that of the normal rotation, the backlash in the accessory gear train can be removed to the extent that a specific crankshaft position can be obtained with accuracy time after time.

Not all timing disks are marked off in the same number of degrees. For example, the disk designed for use on one type of engine is mounted on the fuel pump drive pad. Since the fuel pump is driven at the same speed as the crankshaft, the pointer will describe a complete circle when the crankshaft completes one revolution. Hence, the disk is laid out in one-degree increments throughout a total of 360°. However, the timing disk used on another engine is mounted on top of the magneto, which is driven at one-half crankshaft speed. With this arrangement the crankshaft will move one degree while the pointer moves only one-half a degree. Therefore, the disk is marked off in 720 one-half-degree increments, each one-half degree indicating one full degree of crankshaft travel.

A modification of the timing disk is the timing plate Figure 4–30. The markings will vary according to the specifications of the engine. This plate is installed on the thrust nut corner plate bolts and the pointer attached to the propeller shaft.

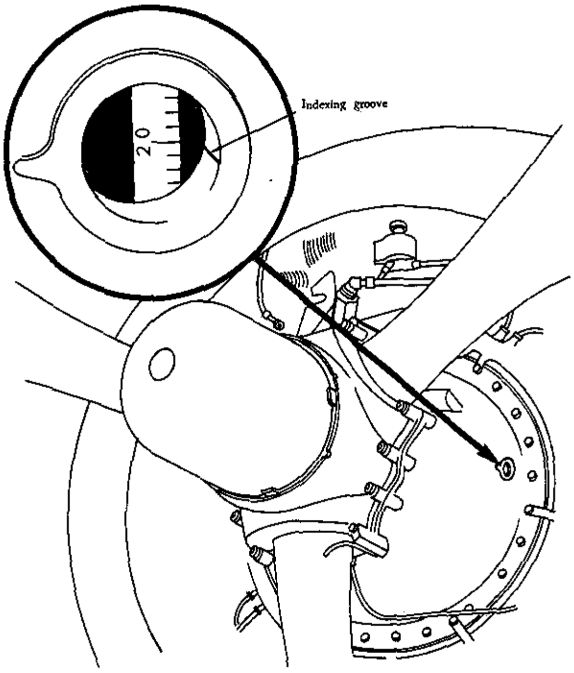


FIGURE 4–29. Typical built-in timing mark on propeller reduction gear.

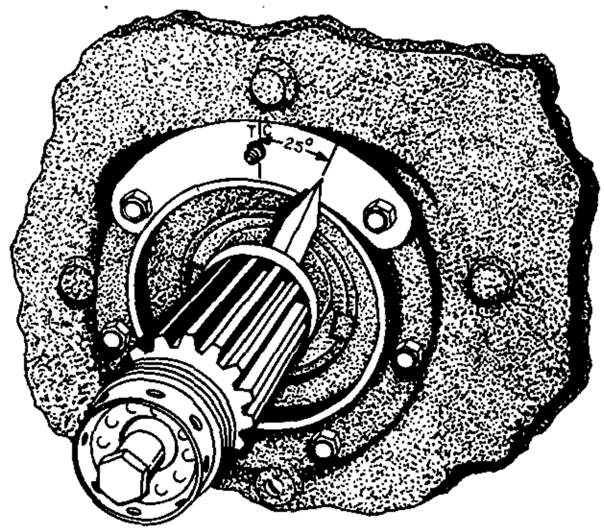


FIGURE 4-30. A timing plate and pointer

Piston Position Indicators

Any given piston position, whether it is to be used for ignition, valve, or injection pump timing, is referenced to a piston position called top dead center. This piston position is not to be confused with a rather hazily defined piston position called top center.

A piston in top center has little value from a timing standpoint because the corresponding crankshaft position may vary from 1° to 5° for this piston position. This is illustrated in figure 4–31 which is exaggerated to emphasize the "no travel" zone of the piston. Notice that the piston does not move while the crankshaft describes the small arc from position A to position B. This "no travel" zone occurs between the time the crankshaft and connecting rod stop pushing the piston upward, and continues until the crankshaft has swung the lower end of the connecting rod into a position where the crankshaft can start pulling the piston downward.

Top dead center is a piston and crankshaft position from which all other piston and crankshaft locations are referenced. When a piston is in the top-dead-center position, it will be a maximum distance from the center of the crankshaft and also in the center of the "no travel" zone. This places the piston in a position where a straight line can be drawn through the center of the crankshaft journal, the crankpin, and the piston pin, as shown in the right-hand diagram of figure 4–31. With such an alignment, a force applied to the piston could not move the crankshaft.

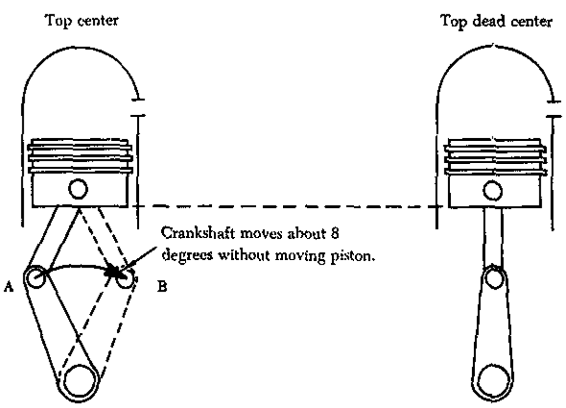


FIGURE 4–31. Illustrating the difference between top center and top dead center.

Perhaps the earliest piston position indicator was a wooden rod or pencil. One end of this simple device was inserted at an angle through the spark plug hole of the timing cylinder until it came to rest on the top far edge of the piston, as shown in figure 4–32. Then the crankshaft was rotated until the piston stopped moving the end of the rod outward. At this point the mechanic would grasp the rod with his thumbnail resting at a point where the rod contacted the top edge of the spark plug hole. With his thumbnail still in this position he would then extract the rod and cut a notch about 1 in. above the thumbnail location. This notch provided the mechanic with an arbitrary reference point somewhere before top dead center.

Such an inexact procedure cannot be relied on to find the same piston position each time. All piston position indicators in use today screw into the spark plug hole so that the indicator always enters the cylinder in exactly the same plane and its indicating rod always contacts the same part of the piston head.

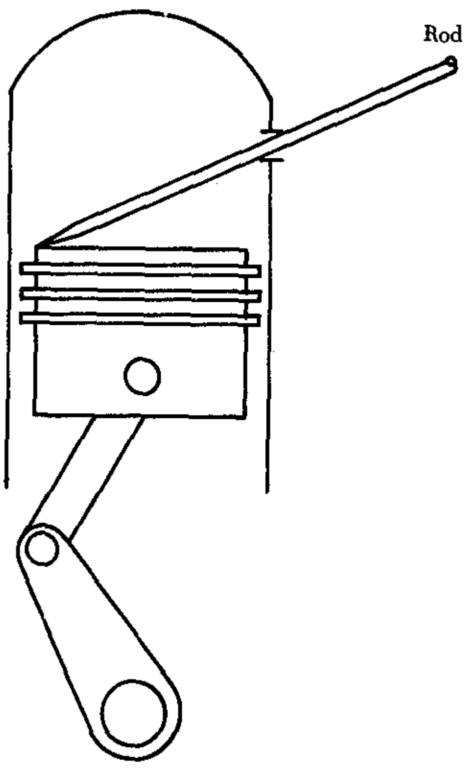


FIGURE 4–32. Simple piston position indicator.

One of the various piston position indicators in use today is a Time-Rite indicator (figure 4–33). It serves the purpose of a piston position indicator and, in a limited degree, as a timing disk. The device consists of two parts, a body shell and a face. The shell is essentially an adapter which screws into the spark plug hole and supports the face. The face snaps into the adapter and contains a spring-loaded compensated indicator arm, a slide pointer, a removable scale calibrated in degrees, an indicator light, and a frame which extends behind the face to form a hinge point for the compensated indicator arm. One end of the compensated arm extends into the cylinder through the spark plug hole and is actuated by piston movement. The other end of the arm extends through a slot in the face and actuates the slide pointer over the scale.

Furnished with the Time-Rite is a variety of different arms and graduated scales. Both arms and scales are compensated for the particular engine for which they are marked. Compensation is necessary because of variations in piston stroke and spark plug hole locations in different cylinders. The arms are compensated by varying their shapes and lengths, and the scales are compensated by the spacing of the degree markings. In this way a particular arm and scale combination will indicate true piston position if used correctly.

To ensure even greater accuracy with the Time-Rite, a small light, powered by a miniature dry cell battery, is mounted in its face. When the compensated arm contacts the slide pointer, an electrical circuit is completed and the light comes on. This light provides greater accuracy because the slide pointer can be positioned at the desired degree setting on the scale and the crankshaft slowly rotated by bumping the propeller shaft until the light just flashes on. The propeller shaft must be moved slowly and carefully so that the arm will not overshoot and move the slide pointer beyond the desired degree setting after the light flashes on.

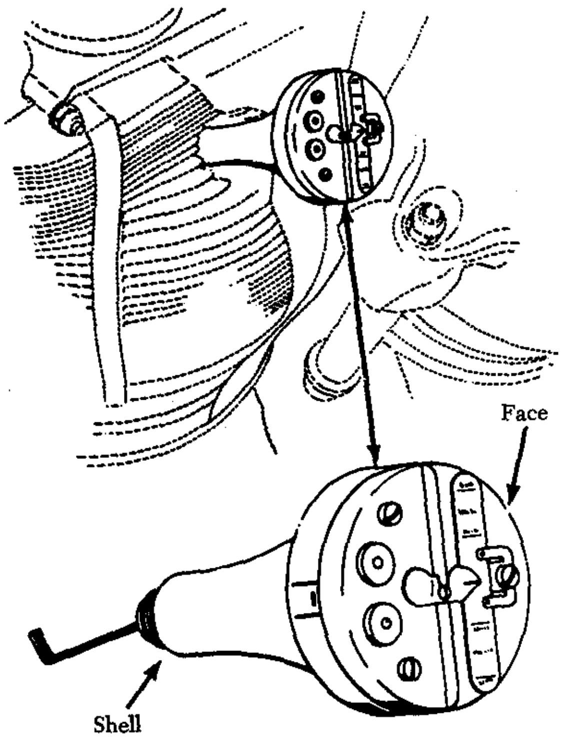


FIGURE 4–33. Time-Rite indicator.

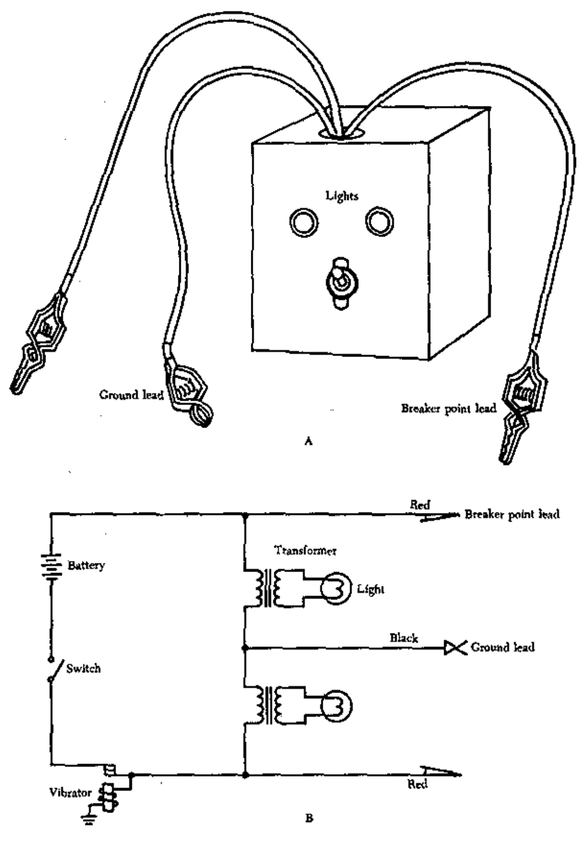


FIGURE 4–34. Timing light and wiring diagram.

There are two other common types of piston position indicators in use, both of which operate on the piston-positioning principle. One features a scale of reference points. The other is simply a light which comes on when the piston touches the actuating arm and goes out when the piston moves below the reach of the arm.

Timing Lights

Timing lights are used to help determine the exact instant that the magneto points open. There are two general types of timing lights in common use. Both have two lights and three external wire connections. Although both have internal circuits that are somewhat different, their function is very much the same. One type of light and its internal circuit are shown in figure 4–34.

Three wires plug into the top of the light box (A of figure 4–34). There are also two lights on the front face of the unit, and a switch to turn the unit on and off. The wiring diagram (B of figure 4–34) shows that the unit contains a battery, a vibrator coil, and two transformers. To use the timing light, the center lead, marked "ground lead," is connected to the case of the magneto being tested. The other leads are connected to the primary leads of the breaker point assembly of the magnetos being timed.

With the leads connected in this manner, it can be easily determined whether the points are open or closed by turning on the switch and observing the two lights. If the points are closed, most of the current will flow through the breaker points and not through the transformers, and the lights will not come on. If the points are open, the current will flow through the transformer and the lights will glow. Some models of timing lights operate in the reverse manner, *i.e.*, the light goes out when the points open. Each of the two lights is operated separately by the set of breaker points to which it is connected. This makes it possible to observe the time, or point in reference to magneto rotor rotation, that each set of points opens.

Most timing lights use dry cell batteries that must be replaced after long use. Attempts to use a timing light with weak batteries may result in erroneous readings because of low current flow in the circuits.

CHECKING THE INTERNAL TIMING OF A MAGNETO

When replacing a magneto or preparing a magneto for installation, the first concern is with the internal timing of the magneto. For each magneto model, the manufacturer determines how many degrees beyond the neutral position a pole of the rotor magnet should be to obtain the strongest spark at the instant of breaker point separation. This angular displacement from the neutral position, known as the E-gap angle, will vary with different magneto models. On one model a "step" is cut on the end of the breaker cam for checking internal timing of the magneto. When a straightedge is laid along this step and it coincides with the timing marks on the rim of the breaker housing, the magneto rotor is then in the E-gap position, and the breaker contact points should just begin to open.

Another method for checking E-gap is to align a timing mark with a pointed chamfered tooth (figure 4–35). The breaker points should be just starting to open when these marks line up.

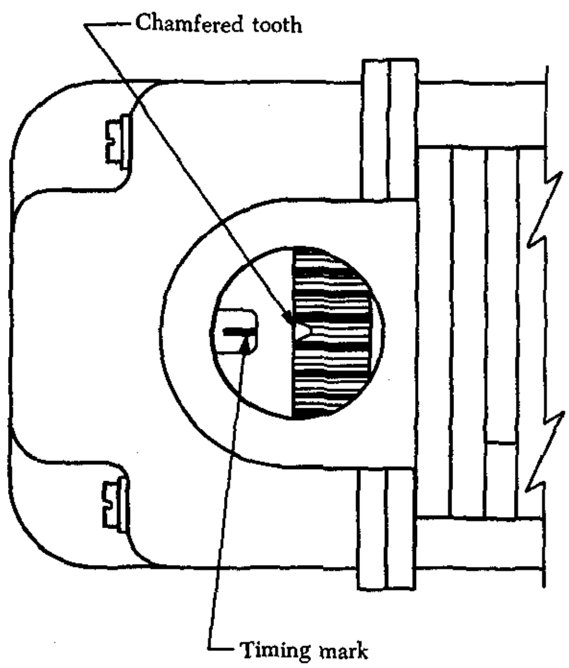


FIGURE 4–35. Timing marks which indicate No. 1 firing position of magneto.

In a third method the E-gap is correct when a timing pin is in place and red marks, visible through a vent hole in the side of the magneto case, are aligned (figure 4–36). The contact points should be just opening when the rotor is in the position just described.

Bench timing the magneto involves positioning the magneto rotor at the E-gap position and setting the breaker points to open when the timing lines or marks provided for that purpose are perfectly aligned.

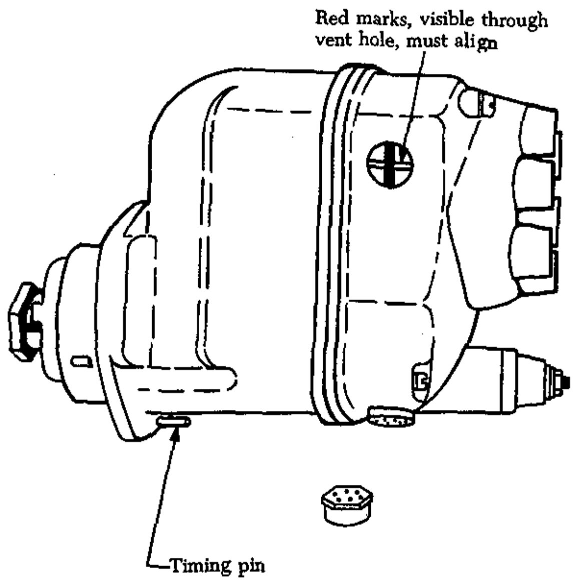


FIGURE 4–36. Checking magneto E-gap.

High-Tension Magneto Bench Timing

In the following discussion, the procedures for bench timing a twin-row radial engine magneto are outlined for an example only. Consult the manufacturer's instructions in every case before bench timing any magneto.

To bench time a magneto certain items of equipment are necessary. Normally included are a timing light, a tool for holding the magneto, a common screwdriver to loosen the point assembly screws, and a straightedge for checking the rotor for E-gap position.

The magneto breaker points are protected by a cover. Removal of this cover exposes the magneto rotor cam and breaker points, as shown in figure 4–37.

To begin bench timing the magneto, connect the two red leads of the timing light to the two primary leads retaining screw. Connect the remaining black lead to the case of the magneto to provide an electrical ground.

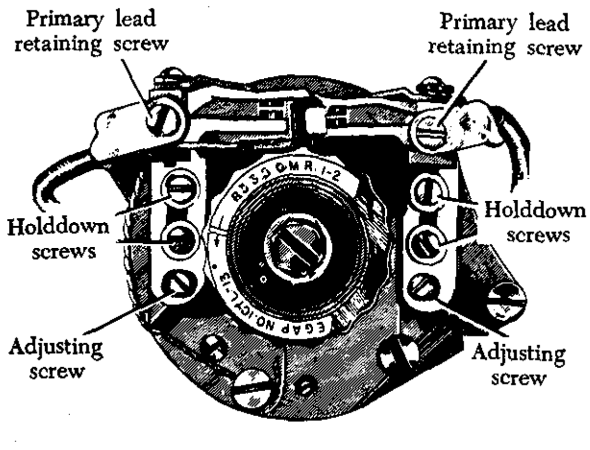


FIGURE 4–37. Magneto breaker points and compensated cam.

With most magnetos of this type, a special tool is used to receive the splined drive shaft of the magneto. This tool holds the magneto with the breaker points in the upright position, and it holds the magneto rotor stationary during the bench timing process. Rotor motion can still be simulated by rotating the magneto around the rotor. Some types of magneto rotor-holding tools are designed with a clamp to lock the rotor to the magneto case to establish the desired relationship between the two.

With the magneto installed on the holding tool and the timing light installed, the position where the timing marks on the magneto rotor and on the magneto align perfectly can be located. Lock the holding tool in this position. With the rotor positioned and locked, both holddown screws (figure 4–37) can be loosened. Then tighten these two screws enough that some drag (friction) is felt when the adjusting screw shifts the grounded breaker point.

Turn on the timing light. Move the adjusting screw back and forth until the timing light for the set of points being adjusted just comes on. Lock this set of breaker points by tightening the two holddown screws without changing the setting of the breaker points.

The magneto rotor lock should be unlocked, and the adjusted set of points should be checked with the straightedge and timing lights to determine that the points open exactly at the E-gap position. This is accomplished by holding the straightedge on the rotor cam step and turning the magneto case around the rotor shaft still supported in the magneto holding device. First, rotate the magneto case in the direction indicated by the arrow on the cam rotor until the light goes out. This indicates that the breaker points have completely closed. Then rotate the magneto case in the opposite direction. This will cause the magneto rotor to again come back to the E-gap position in the normal direction of rotation. If the setting is correct, the magneto rotor cam will line up in the E-gap position, as indicated by the straightedge, at the exact instant that the timing light comes on to indicate that the points are open. The correct internal timing of one set of breaker points has been accomplished.

There are several ways to set the remaining set of breaker points to open at the E-gap position. Perhaps the easiest method is to use the already adjusted set of breaker points as a check point. By using the light indication of the adjusted points as a true reference point for E-gap position, the second set can be synchronized to open at exactly the same time.

When the two holddown screws on the second set of points (figure 4–37) are loosened enough to permit the adjustment screw to move the grounded part of the points, the breaker points can be adjusted until the light for this set of points comes on at exactly the same time as the first set. Then the lockscrews should be tightened without changing the position of the breaker points before rotating the magneto case to see that both lights come on simultaneously. The magneto is now ready to be installed on the engine. This requires timing the magneto to the engine.

Timing the High-Tension Magneto to the Engine

When replacing magnetos on aircraft engines, two factors must be considered: (1) The internal timing of the magneto, including breaker point adjustment, which must be correct to obtain maximum potential voltage from the magneto, and (2) the crankshaft position at which the spark occurs.

A breaker point gap should never be compared with another, since it would not be known if either set of breaker points were opening at the proper number of degrees before top dead center of the timing position of the engine. The magneto must be timed by first adjusting the internal timing of the magneto and then by checking and adjusting the ignition points to open at this position. If the reference timing mark for the magneto lines up when the timing piston is at a prescribed number of degrees ahead of true top dead center and both the right and left set of breaker points open at that instant and remain open for the prescribed number of degrees, the internal magneto timing is correct, proper magneto-to-engine timing exists, and all phases of magneto operation are synchronized. In no case should the breaker points be adjusted when the internal timing of the magneto, as designated by internal timing reference marks, is off in relation to the prescribed piston position.

For timing the magneto to the engine in the following example, a timing light is used. The timing light is designed in such a way that one of two lights will come on when the points open. The timing light incorporates two lights; hence, when connecting the timing light to the magneto, the leads should be connected so that the light on the right-hand side of the box represents the breaker points on the right side of the magneto, and the light on the left-hand side represents the left breaker points. The proper connection of wires can be established by turning the timing light on and then touching one of the red wires against the black wire. If the right light goes out, the red lead used should be connected to the magneto housing or the engine to effect a ground. When using the timing light to check a magneto in a complete ignition system installed on the aircraft, the master ignition switch for the aircraft must be turned on and the ignition switch for the engine turned to "both." Otherwise, the lights will not indicate breaker point opening. With the ignition switch on and the timing light connected, the magneto is rendered inoperative; hence, no firing impulses can occur when the propeller is turned.

After determining that the magneto internal timing is correct, turn the engine crankshaft until the piston of the No. 1 cylinder is in the firing position on the compression stroke. The firing position can be determined by referring to the engine manufacturer's service manual. Locate the firing position by using a piston position indicator.

To establish crankshaft position with the piston position indicator:

(1) Remove the most accessible spark plug from the No. 1 cylinder.

(2) Install the correct contact arm and calibrated scale for the engine involved. (Consult applicable manufacturer's instructions for correct contact arm and calibrated scale.)

(3) Pull the propeller through in the direction of rotation until the No. 1 piston is coming up on the compression stroke. This can be determined by holding the thumb over the spark plug hole until the compression blows the thumb off the hole.

(4) Separate the piston position indicator assembly and screw the housing into the spark plug bushing until it is seated firmly. Insert the indicator assembly into the body with the hook-end up or down as indicated on the scale.

(5) Push the slide pointer upward in the slot until it reaches the end of the slot and is stopped by the indicator arm (figure 4–38).

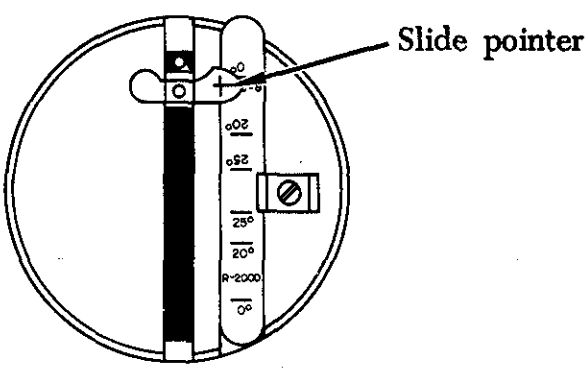


FIGURE 4–38. Positioning the slide pointer.

(6) Pull the propeller through slowly in the direction of rotation until the indicating arm has moved the slide pointer the maximum distance, and the indicating arm starts to move back upward in the slot (figure 4–39).

(7) Move the calibrated scale so that the zero mark on the scale aligns with the scribe mark on the slide pointer.

(8) Move the slide pointer back to the top of the slot, or until it contacts the indicating arm.

(9) Turn the propeller in the direction opposite to which it normally rotates until the indicating arm has returned to the top of the slot.

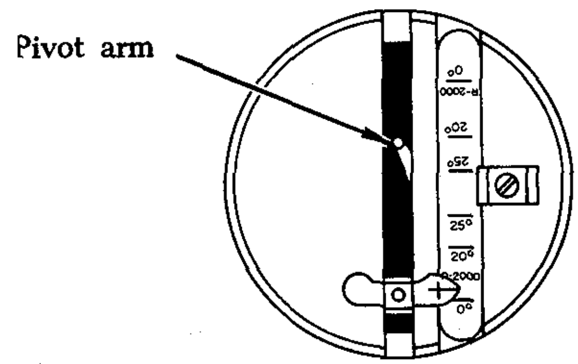


FIGURE 4–39. Slide pointer at maximum position.

(10) Recheck the zero mark of the calibrated scale against the reference mark on the slide pointer (figure 4–40).

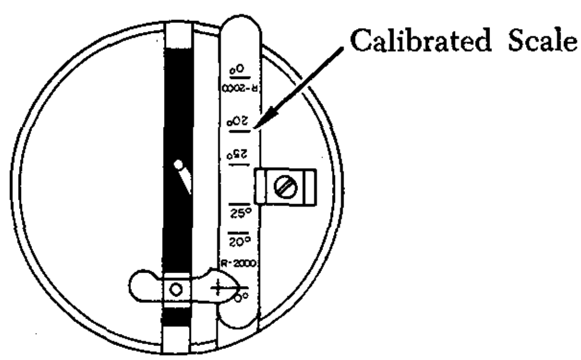


FIGURE 4–40. Rechecking the zero mark against reference mark on slide pointer.

(11) Again move the slide pointer to the top of the slot, or until it contacts the indicating arm.

(12) Pull the propeller through in the direction of rotation. Movement of the slide pointer by the indicating arm will indicate crankshaft position in relation to true top dead center on the calibrated scale (figure 4–41).

(13) Set the engine crankshaft at the prescribed number of degrees ahead of true top dead center (ignition timing) as specified in the applicable manufacturer's instruction.

While holding the magneto cam in the firing position for the No. 1 cylinder, as indicated by the alignment of the reference marks for the magneto, install the magneto splined drive into the engine drive.

Connect the timing light to the magneto and breaker points, and with the light and ignition switch turned on, rotate the magneto assembly, first in the direction of rotation and then in the opposite direction. Accomplish this procedure to determine that the timing light goes off and then on when the cam lobe for the No. 1 cylinder, usually marked by a white dot, lifts the breaker points as the magneto is rotated on its mount.

If the slots in the mounting flange of the magneto do not permit sufficient movement to effect breaker point opening for the No. 1 cylinder, move the magneto out of position far enough to permit turning the magneto drive shaft one spline in the advance or retard direction. Then install the magneto in position again and repeat the previous check for point opening.

After the magneto spline-to-engine female spline relationship has been established (permitting point opening and closing with slight rocking of the magneto), install the magneto attaching nuts on the studs and tighten slightly. The nuts must not be so tight as to prevent the movement of the magneto assembly when the magneto mounting flange is tapped with a mallet.

While holding the backlash out of the magneto gears and drive coupling, tap the magneto to advance or retard it until the timing marks align (figure 4–42). This times the internal timing of the magneto to the prescribed number of degrees before top center. After completing this adjustment, tighten the mounting nuts. Then move the propeller opposite the direction of rotation one blade, and then pull it slowly in the direction of rotation until the crankshaft position is again at the prescribed

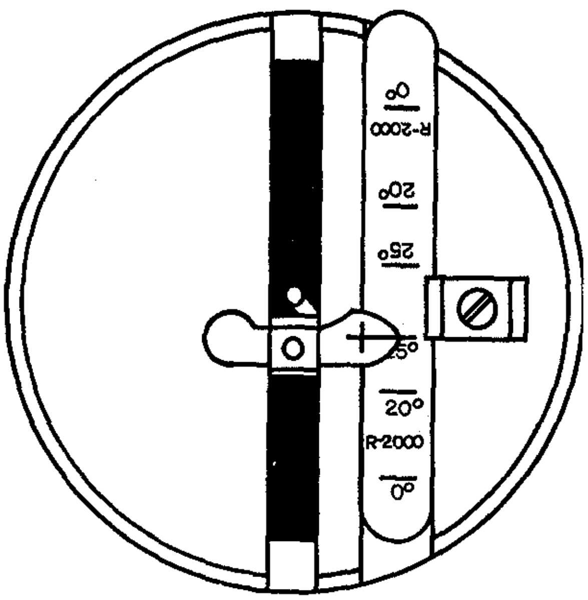


FIGURE 4–41. Moving crankshaft to piston firing position.

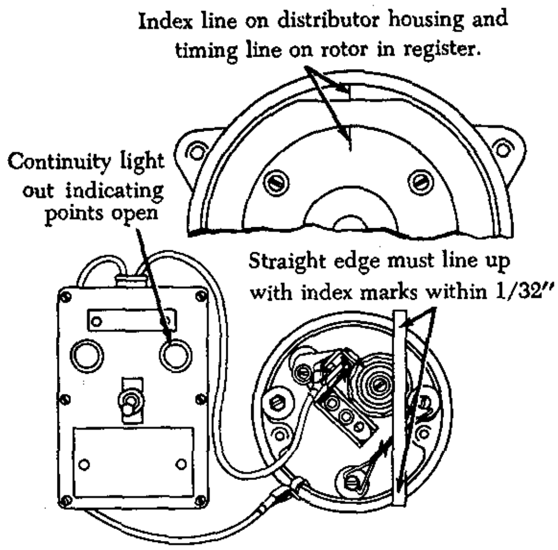


FIGURE 4–42. Scale in position for checking E-gap.

number of degrees ahead of top dead center. (The purpose of this check is to eliminate the possibility of error because of backlash in the engine gear-train assembly and magneto gears.) If the timing mark does not line up, loosen the mounting nuts and shift the magneto until the scale or straightedge will line up with the timing mark when the propeller is pulled through to the prescribed number of degrees.

Reconnect the timing light. Move the propeller one blade opposite the direction of rotation and then, while observing the timing light, move the propeller in the direction of rotation until the prescribed number of degrees ahead of top dead center is reached. Be sure that the lights for both sets of points come on within one-half-degree crankshaft movement of the prescribed crankshaft position.

After the points have been adjusted as necessary, recheck the point-adjusting lockscrew for tightness. Always check the point opening after tightening the lockscrew.

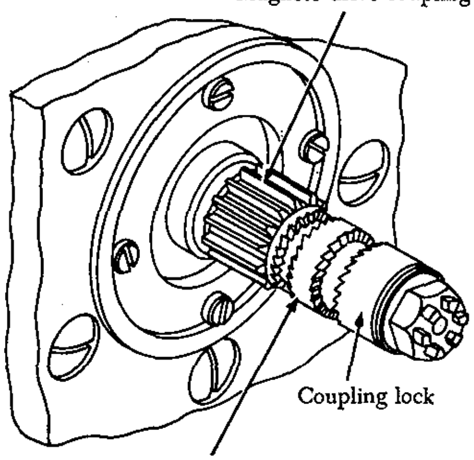


FIGURE 4–43. Magneto ratchet arrangement.

Timing Magneto Using Magneto Drive Ratchet

Because of the ignition harness design on some engines, it is not possible to rotate the magneto on its mount to accomplish minute changes in magneto timing. Provisions for accomplishing magneto-to-engine timing are provided by a ratchet arrangement on the end of the magneto drive shaft (figure 4–43). When the drive shaft nut has been loosened about 1/8 in., the clamping action of the ratchet mechanism is eliminated and the drive coupling is held against the ratchets only by a spring. In this position the coupling can be turned, producing a clicking effect between the ratchets, which are held by the spring. A typical timing ratchet has 24 teeth on one side and 23 teeth on the other side. Turning the drive coupling one click or tooth in the clockwise direction moves it 15° in a clockwise direction. Turning the drive coupling counterclockwise one click or tooth moves it counterclockwise 15.65°. Therefore, turning the drive coupling clockwise one click, then counterclockwise one click, gives a net change of 0.65° in a counterclockwise direction.

To time this type of magneto, special timing tools are usually prescribed by the applicable manufacturer's instruction. Otherwise, the instructions follow generally those discussed previously, except that fine timing adjustments are made to the magneto drive coupling ratchet.

Timing Rigid-Mounted Magneto Without Special Tools

Some types of high-tension magnetos can be timed to the engine without special tools by using procedures similar to the following example:

(1) Install the proper equipment for establishing crankshaft position.
(2) Set the crankshaft to the prescribed number of degrees ahead of top center for the ignition to fire as specified in the applicable manufacturer's instruction.
(3) Remove the magneto cover and place a straightedge or scale along the cam step (A of figure 4–44). Align the straightedge with the timing mark on the rim of the casting.
(4) While holding the cam in the firing position, place the magneto in position on the engine, allowing the cam to move as necessary so that the splined drive gear of the magneto will slip into place in the engine drive.
(5) Hold the cam opposite the direction of rotation to remove slack from the magneto and the engine gear train. Then, while holding the slack out of the gear drive train, place a straightedge across the step in the magneto cam and put a pencil mark on the housing (B of figure 4–44).
(6) Remove the magneto from the engine, and using a straightedge on the cam step, align

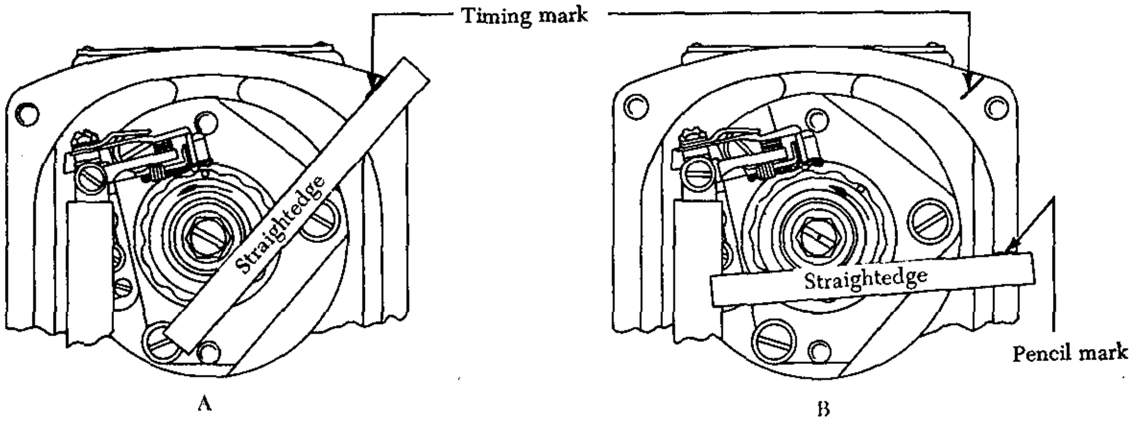


FIGURE 4–44. Aligning straightedge.

the cam step with the pencil mark on the housing. While holding the cam in this position, apply force to the magneto drive in the direction of rotation to remove the slack from the gears in the magneto. With the slack removed and the step on the cam aligned with the pencil mark, make another pencil mark on one spline of the drive shaft and a corresponding mark on the casting (A of figure 4–45).

(7) Turn the magneto cam to the No. 1 firing position where the straightedge lines up with the timing mark (as in A of figure 4–44). The result is a drive coupling alignment similar to that shown in view B of figure 4–45).

(8) While holding the cam in its correct timing position, ratchet the drive coupling until the marked tooth of the spline lines up with the pencil mark on the casting (A of figure 4–45).

(9) Tighten the drive shaft nut of the magneto and secure it with a cotter pin. Now install the magneto while holding the cam in the No. 1 firing position.

(10) After the magneto is installed and before tightening the attaching nuts, recheck the alignment of the cam step with the timing mark. When making this check, rotate the cam opposite the direction of rotation to remove the slack from the magneto and engine gears.

(11) Move the propeller one blade in the opposite direction of rotation. Then move the propeller slowly in the direction of rotation until the crankshaft is at the designated number of degrees ahead of top dead center (firing position). Recheck the alignment of the straightedge with the reference mark. If correct alignment is not obtained, remove the magneto and change the ratchet mechanism on the magneto drive shaft as necessary.

(12) Ground the black lead of the timing light to the engine, and connect one of the red leads to the magneto breaker points. Turn the propeller in the opposite direction of

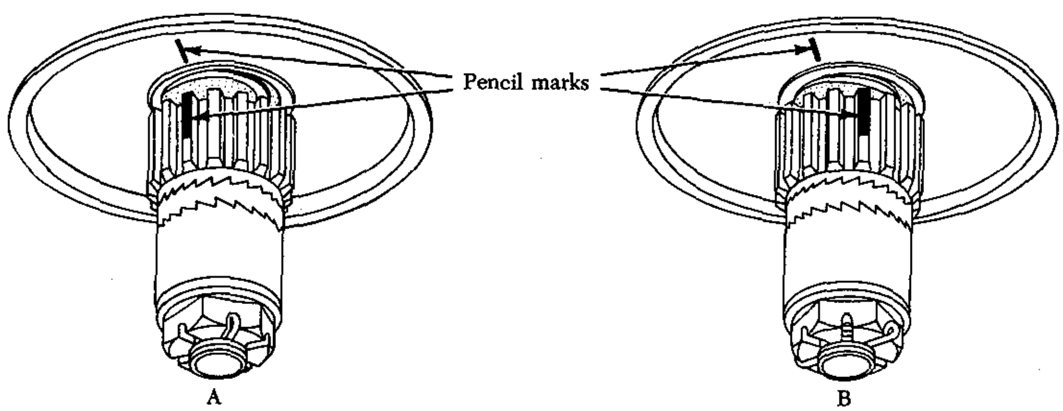


FIGURE 4–45. Marking drive spline.

rotation. Then, with the timing light turned on, move the propeller slowly in the direction of rotation until the points break for the No. 1 cylinder. If the points do not break within plus or minus one-half-degree crankshaft travel of the position specified in the manufacturer's instructions, repeat the timing procedure.

TIMING HIGH-TENSION SYSTEM DISTRIBUTOR FINGERS

Distributor fingers are basic parts for right and left magnetos on many models of engines. When the distributors are separate, a vernier adjustment is provided for proper distributor-finger timing. Distributor fingers on some engines are timed by shifting the distributor finger drive flange and selecting the proper mounting boltholes for the distributor finger. On any engine incorporating separate distributors, be sure that the distributor finger aligns with the electrode for No. 1 cylinder when the crankshaft is the prescribed number of degrees ahead of top center for the magneto to fire.

On engines, proper distributor finger timing is obtained by first establishing true top-dead-center position. Then the crankshaft is set at the prescribed number of degrees ahead of top center for the ignition to fire. Finally, the distributor finger is adjusted to align with the No. 1 electrode when all backlash has been removed from the distributor finger drive gears.

Since there are several different types of high-tension system distributors, always consult applicable manufacturer's instructions before timing a distributor to an engine. A summary of the procedures used in timing one type of distributor is included as an example of typical procedures.

To time the distributor to the engine, loosen the housing and remove some of the spark plug leads attached to the distributor. The housing is loosened by removing the base clamp ring and loosening the manifold clamp rings. Then the distributor housing is pushed back to expose the distributor finger.

The next step in the distributor timing procedure is to remove the distributor finger to expose the nut which locks the drive coupling. Then loosen the coupling nut and install the proper distributor timing tool. Rotate the coupling unit against the normal line with the scribed line on the parting surface. Tighten the coupling nut in this position after all backlash has been removed from the distributor drive gears. The timing tool can now be removed and the distributor finger installed.

The distributor housing assembly can now be placed in position on the distributor base. Secure all clamp rings on the distributor and install the spark plug leads that were removed. Safety the distributor as necessary.

Low-Tension Magneto System Timing Procedures

In timing the magneto to the engine, a number of different indicators may be used to locate the piston's top-dead-center position. In this example, a top center indicator light (figure 4–46) will be used with a disk attached to the starter pad on the engine accessory section.

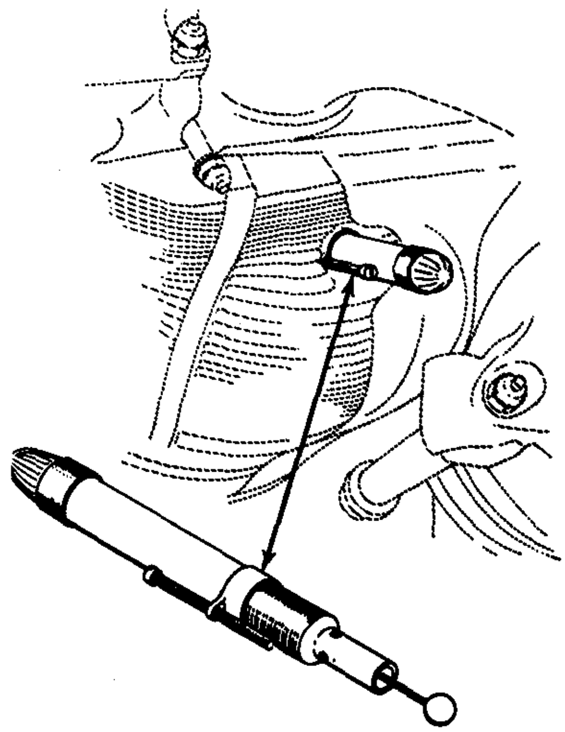


FIGURE 4–46. Top center indicator light.

To use the top center indicator light for finding top dead center, turn the propeller in the normal direction of rotation until the compression stroke is found. Install the top center indicator light in the spark plug hole. Turn the propeller in the normal direction of rotation until the light comes on, which indicates that the piston has moved the indicator arm. When the light comes on, stop and record the timing disk degree reading. Move the propeller in the direction of normal rotation until the light goes out. At this time, record the degree reading appearing on the timing disk. Compute the number of degrees of travel from the time the light came on until it went out. Halfway between the light-on and the light-out indications is top dead center.

Before installing any part of the ignition system, always make sure that the unit being installed has been properly checked and inspected for correct operation. Examine all exterior screws for tightness, and see that all safety wire is installed where necessary. Use a new gasket on the mounting pad.

After locating top dead center, back the propeller approximately three-fourths of a turn in the opposite direction of rotation. Then turn the propeller in the direction of rotation until the piston is in the normal firing position.

Make sure the magneto drive shaft has been tightened and a cotter pin installed. Remove the spring clip from the timing plunger, which holds the plunger in the "out" position. There are four notches in the magneto shaft; the plunger fits into these notches during the timing operation to hold the magneto shaft in the correct E-gap position. Press down the plunger and turn the magneto drive shaft until the plunger falls into one of the notches. Then set the magneto on the engine mounting pad (figure 4–47), holding the plunger in position so that it does not slip.

If the spline on the drive member will not mesh when the magneto is properly positioned on the mounting flange, move the magneto away from the mounting pad and rotate the magneto shaft 90° so that the plunger bottoms in the next slot on the

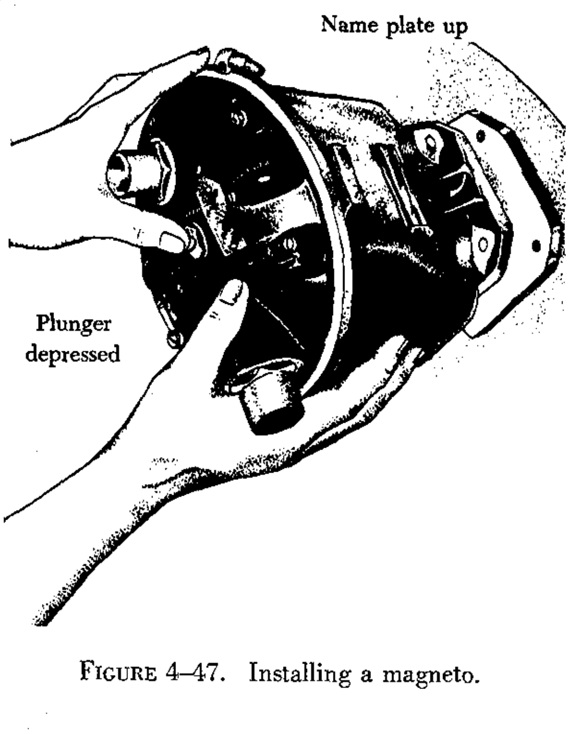


FIGURE 4–47. Installing a magneto.

magneto shaft. Put the magneto back on the mounting pad again and see if the splines and the mounting flange slots will match. If they do not match, repeat this procedure until the splines will mesh and the magneto is positioned properly on the mounting flange. After the correct position has been found, hold the magneto in this position and tighten the stud nuts which secure the magneto to the engine mounting flange.

To determine that the magneto is mounted in the E-gap position, slowly turn the propeller. As it nears the normal firing position for No. 1 cylinder, push the plunger in. It should fall in a notch when the firing position is reached.

Installing Low-Tension System Distributor

The distributor in a low-tension system, such as that discussed in the foregoing low-tension system, is installed as a separate unit. It is flange-mounted, with elongated slots used for adjustments.

Before installing the distributor, always check the master rod designation on the distributor plate against the engine data plate to see that the distributor has the correct breaker, corresponding to the master rod location in the engine.

Leave the piston at the specified number of degrees before top dead center used for timing the magneto. To prevent foreign particles from entering the unit, do not remove the protective covering until just before installing the distributor. At that time, remove the clamping ring and take off the distributor's protective cover. Rotate the distributor drive shaft until the line marked "1" on the finger is lined up with the line marked "Time-Open" on the collector plate, as shown in figure 4–48.

Keeping the distributor in this position, install it on the mounting flange, making sure the studs are aligned approximately in the center of the elongated slots in the distributor mounting flange as shown in figure 4–48.

If they do not align themselves in the middle of the flange slots, remove the distributor and shift the drive gear one tooth on its spline. Then reinstall the magneto, making sure the finger is still lined up with "1" position. When the right setting has been found for the drive gear, take the distributor off the mounting pad, tighten the end nut, and install a new cotter pin in the castellated nut. Reinstall the distributor and screw the holddown nuts finger-tight on the mounting bolts.

Connect the timing light red lead to the insulated side of the "1" main breaker and the black lead to the housing, as shown in figure 4–49. Then rotate

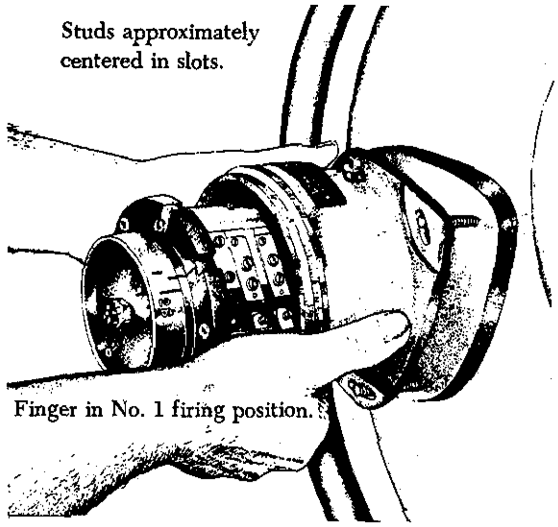


FIGURE 4–48. Distributor installation.

the distributor clockwise on its mounting pad until the timing light comes on, indicating that the points are just beginning to open. Tighten the flange hold-down nut with the distributor in this position. Mount the other distributor on the engine, using the same procedure.

After both distributors have been installed, their operation must be synchronized. Connect a red lead of the timing light to each main breaker and the black lead to ground. Back the propeller at least a fourth of a turn, and then turn it slowly in the direction of normal rotation through the No. 1 firing position to see if both main breaker points are opening at the same instant. If both timing lights come on at the same time, the distributors are synchronized.

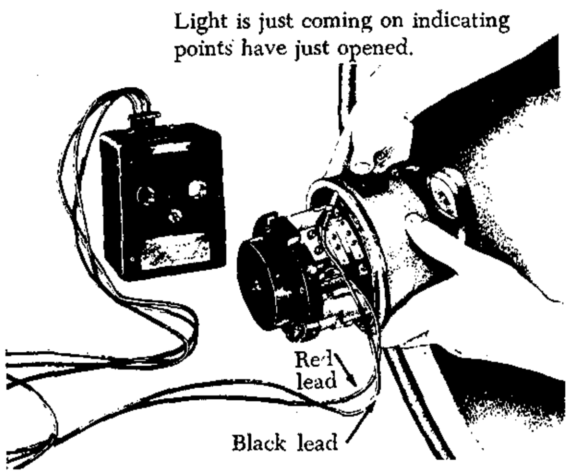


FIGURE 4–49. Timing the low-tension distributor to the engine.

If the lights do not come on at the same time, the distributors must be re-synchronized. To do this, turn the second distributor slightly on its mounting pad until both sets of points (one on each distributor) open at the same instant, which must also be at the instant No. 1 cylinder reaches its firing point.

Replace the distributor heads and secure the clamping rings on the distributors. The ignition system is now ready for an operational check,

Performing Ignition System Checks

There are normally three ignition checks performed on aircraft during engine runup. The first is performed during engine warmup. The second is performed at field barometric manifold pressure. The third is performed prior to engine shutdown.

The first ignition check is normally made during warmup. Most manufacturers' instructions recommend this check during the warmup period. Actually, this check is a combination of the ignition system check and ignition switch check and is used to check the ignition system for proper functioning before other checks are made. The second check is performed as the ignition system check and is used to check the individual magnetos, harnesses, and spark plugs. The third check is performed as the ignition switch check and is used to check the switch for proper grounding for ground safety purposes.

The ignition system check is usually performed with the power check. The ignition check is sometimes referred to as the field barometric check, because on large engines it is performed with the engine operating at a manifold pressure equal to the field barometric pressure. The power check is also performed at the same manifold pressure setting. The ignition check should not be confused with the full throttle check. The exact r.p.m. and manifold pressure for making this check can be found in the applicable manufacturer's instructions.

The barometric pressure used as a reference will be the reading obtained from the manifold pressure gage for the engine involved prior to starting the engine and after engine shutdown. After reaching the engine r.p.m. specified for the ignition system check, allow the r.p.m. to stabilize. Place the ignition switch in the "right" position and note the r.p.m. drop on the tachometer. Return the switch to the "both" position. Allow the switch to remain in the "both" position for a few seconds so that the r.p.m. will again stabilize. Place the ignition switch in the "left" position and again note the r.p.m. drop. Return the ignition switch to the "both" position.

In performing this check, lightly tap the rim of the tachometer to ensure that the tachometer indicator pointer moves freely. A sticking tachometer pointer can conceal ignition malfunctions. There is also a tendency to perform this check too rapidly, which will result in wrong indications. Single ignition operation for as long as 1 minute is not considered excessive, but this time interval generally should not be exceeded.

Record the amount of the total r.p.m. drop which occurs immediately and also the amount which occurs slowly for each switch position. This breakdown in r.p.m. drop provides useful information. This ignition system check is usually performed at the beginning of the engine run-up, because if the r.p.m. drops were not within the prescribed limits, it would affect all other later checks.

Ignition Switch Check

The ignition switch check is usually made at 700 r.p.m. On those aircraft engine installations that will not idle at this low r.p.m., set the engine speed to the minimum possible to perform this check. When the speed to perform this check is obtained, momentarily turn the ignition switch to the "off" position. The engine should completely quit firing. After a drop of 200 to 300 r.p.m. is observed, return the switch to the "both" position as rapidly as possible. Do this quickly to eliminate the possibility of afterfire and backfire when the ignition switch is returned to "both."

If the ignition switch is not returned quickly enough, the engine r.p.m. will drop off completely and the engine will stop. In this case, leave the ignition switch in the "off" position and place the mixture control in "idle-cutoff" position to avoid overloading the cylinders and exhaust system with raw fuel. When the engine has completely stopped, allow it to remain inoperative for a short time before restarting.

The ignition switch check is performed to see that all magneto ground leads are electrically grounded. If the engine does not cease firing in the "off" position, the magneto ground lead, more commonly referred to as the "P" lead, is open; and the trouble must be corrected.

Replacement of Ignition Leads

When defective leads are revealed by an ignition harness test, continue the test to determine whether the leads or distributor block are defective. If the difficulty is in an individual ignition lead, determine whether the electrical leak is at the spark plug elbow or elsewhere. Remove the elbow, pull the ignition lead out of the manifold a slight amount, and repeat the harness test on the defective lead. If this stops the leakage, cut away the defective portion of the lead, and re-install the elbow assembly, integral seal, and cigarette (figure 4–50).

If the lead is too short to repair in the manner just described, or the electrical lead is inside the harness, replace the defective lead. If the harness is not the re-wirable type, the entire harness must be replaced. Ignition lead replacement procedures are as follows:

(1) Disassemble the magneto or distributor so that the distributor block is accessible.

(2) Loosen the piercing screw in the distributor block for the lead to be replaced, and remove the lead from the distributor block.

(3) Remove approximately 1 in. of insulation from the distributor-block end of the defective lead and approximately 1 in. of insulation from the end of the replacement cable. Splice this end to the end of the lead to be replaced and solder the splice.

(4) Remove the elbow adapter from the spark-plug end of the defective lead, and then pull the old lead out and the new lead into the harness. While pulling the leads through the harness, have someone push the replacement lead into the ignition manifold at the distributor end to reduce the force required to pull the lead through the ignition manifold.

(5) When the replacement lead has been pulled completely through the manifold, force the ignition lead up into the manifold from the distributor-block end to provide extra length for future repairs which may be necessary because of chafing at the spark plug elbow.

(6) Remove approximately 3/8 inch of insulation from the distributor-block end. Bend the ends of the wire back and prepare the ends of the cable for installation into the distributor-block well as illustrated in figure 4–49. Insert the lead in the distributor and tighten the piercing screw.

(7) Remove approximately 1/4 inch of insulation from the spark plug end of the lead and install the elbow, integral seal, and cigarette as illustrated in figure 4–50.

(8) Install a marker on the distributor end of the cable to identify its cylinder number. If a new marker is not available, use the marker removed from the defective cable.

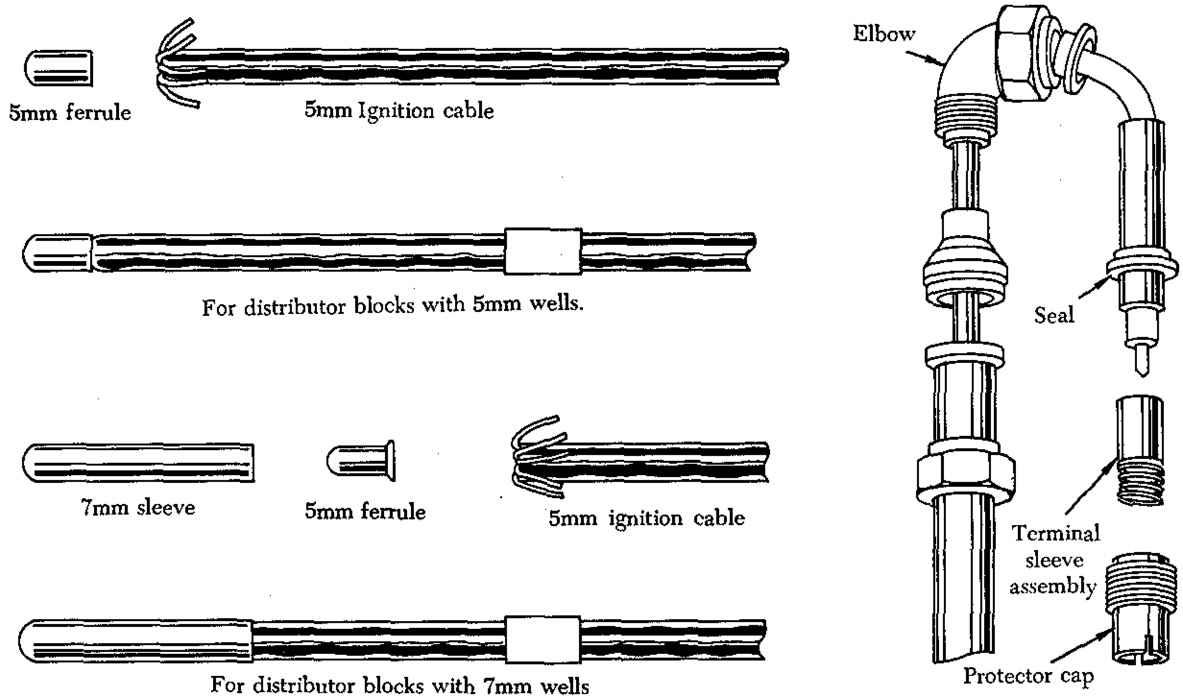


FIGURE 4–50. Replacement procedure for ignition lead terminals.

Replacement of Ignition Harness

Replace a complete rewirable ignition harness only when the shielding of the manifold is damaged or when the number of defective leads makes it more practical to replace the harness than to replace the individual leads. Replace a cast-filled harness only when leakage in the cast-filled portion is indicated. Before replacing any harness to correct engine malfunctioning, make extensive ignition harness tests. Typical procedures for installing an ignition harness are:

(1) Install the ignition harness on the engine. Tighten and safety the holddown nuts and bolts, and install and tighten the individual lead brackets according to instructions. The ignition harness is then ready for connection of the individual leads to the distributor block. A band is attached to each lead at the distributor end of the harness to identify the cylinder for the lead. However, each lead should be checked individually with a continuity or timing light prior to connecting it.

(2) Check for continuity by grounding the lead at the cylinder and then checking at the distributor-block end to establish that the lead grounded is as designated on the band for the lead.

(3) After checking all leads for proper identification, cut them to the proper length for installation into the distributor block. Before cutting the leads, however, force them back into the manifold as far as possible to provide surplus wire in the ignition manifold. This extra wire may be needed at a later date in the event that chafing of a lead at the spark plug elbow necessitates cutting a short section of wire from the spark-plug end of the harness. After cutting each lead to length, remove approximately 3/8 inch of insulation from the end and prepare the lead for insertion into the distributor block. Before installing the lead, back out the set screw in the distributor block far enough to permit slipping the end of the wire into the hole without force. Insert the lead into the block and tighten the set screw. Connect the wires in firing order, i.e., the first cylinder to fire No. 1 location on the block, the second in the firing order to No. 2 location, etc. Distributor block-to-cylinder connections for various engines are shown in the chart in figure 4–51.

After connecting each lead, check continuity between the lead and its distributor-block electrode with a continuity light or timing light. To perform

Distributor Block Number	18-Cylinder Radial	14-Cylinder Radial	9-Cylinder Radial	7-Cylinder Radial	6-Cylinder Horizontally Opposed	4-Cylinder Horizontally Opposed
1	1	1	1	1	1	1
2	12	10	3	3	4	3
3	5	5	5	5	5	2
4	16	14	7	7	2	4
5	9	9	9	2	3	
6	2	4	2	4	6	
7	13	13	4	6		
8	6	8	6			
9	17	3	8			
10	10	12				
11	3	7				
12	14	2				
13	7	11				
14	18	6				
15	11					
16	4					
17	15					
18	8					

FIGURE 4–51. Chart for connecting leads of distributor blocks of various engines.

this check, ground the ignition lead (to the engine) at the spark-plug end, ground one test lead, and touch the other test lead to the proper distributor-block electrode. If the light does not indicate a complete circuit, the set screw is not making contact with the ignition wire, or the lead is connected to the wrong block location. Correct any faulty connections before installing the distributor block.

Checking Ignition Booster Systems

To check the booster coil for proper operation, remove the high-tension lead from the booster coil. Install one end of a length of 7-mm. test ignition cable in the booster coil and hold the other end 3/8 inch from a suitable ground. Have an assistant make sure the manual mixture control is in the "idle cutoff" position, the fuel shutoff valve and booster pump for that engine are in the "off" position, and the battery switch is on. If the engine is equipped with an inertia or combination starter, the assistant should close the engage or mesh switch. Do not energize the starter prior to engaging it. If the engine is equipped with a direct-cranking starter, be sure the propeller is clear and close the start switch. As the engage, mesh, or start switch (depending on the engine starting system) is closed, continuous sparking should be observed from the end of the test lead. These sparks should be fat and snap with a bright blue arc to be considered satisfactory. If the booster coil is operating satisfactorily, signal the assistant to release the starter switch. Then remove the test lead and re-install the regular high-tension lead in the booster coil.

To check the induction vibrator, make sure the manual mixture control is in "idle cutoff," the fuel shutoff valve and booster pump for that engine are in the "off" position, and the battery switch is on. Since the induction vibrator will buzz whether the ignition switch is "on" or "off," leave the switch "off" during the check. If the engine is equipped with an inertia or combination starter, make the check by closing the engage or mesh switch; if the engine is equipped with a direct-cranking starter, see that the propeller is clear and close the start switch. An assistant, stationed close to the induction vibrator, should listen for an audible buzzing sound. If the unit buzzes when the starter is engaged or cranked, the induction vibrator is operating properly.

SPARK PLUG INSPECTION AND MAINTENANCE

Spark plug operation can often be a major source of engine malfunctions because of lead, graphite, or carbon fouling and because of spark plug gap erosion. Most of these failures, which usually accompany normal spark plug operation, can be minimized by good operational and maintenance practices.

Carbon Fouling of Spark Plugs

Carbon fouling (figure 4–52) from fuel is associated with mixtures that are too rich to burn or mixtures that are so lean they cause intermittent firing. Each time a spark plug does not fire, raw fuel and oil collect on the nonfiring electrodes and nose insulator. These difficulties are almost invariably associated with an improper idle mixture adjustment, a leaking primer, or carburetor malfunctions that cause too rich a mixture in the idle range. A rich fuel/air mixture is detected by soot or black smoke coming from the exhaust and by an increase in r.p.m. when the idling fuel/air mixture is leaned to "best power." The soot that forms as a result of overly rich, idle fuel/air mixtures settles on the inside of the combustion chamber because the heat